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IX.

TRIAL TRIPS AND THE LESSONS TO BE LEARNED FROM THEM.

[A discussion at the monthly meeting of the Washington branch of the Society, December 18th, 1890, Chief Engineer N. P. Towne, U. S. Navy, President, in the chair.]

ASSISTANT ENGINEER W. M. MCFARLAND, U. S. NAVY.—I had hoped that we would be favored this evening with a paper on this subject from one of our members, who was an important factor in the success of the trials of the *Boston* and the *Chicago*, but he has been unable to prepare the paper, owing to the great amount of work in the office. Feeling that the subject is one which is likely to provoke a very profitable discussion, the Council decided to take it up.

In order to bring our ideas into shape, I shall endeavor to sketch a hasty outline of what might be the divisions of a paper on the subject, trusting that the members present, many of whom have been on trial trips recently, will talk freely and give us all the benefit of what they have learned.

It will probably be best to elaborate the discussion under the general heads of progressive trials and the contract or four-

hour full-power trials. If time permits, we might consider also special trials of boilers and engines.

It is not necessary to go into a description of the progressive trials, because they have been so thoroughly worked over that every one knows about how they are conducted. The first in this country with vessels of any size were those which took place at Newport in August and September of 1889. Having assisted in taking the data and working out the results of these, I can say that their value has been very great.

Among the points brought out was the difficulty under the arrangements ordinarily existing on board ship for accurate simultaneous observations of time and revolutions. As a consequence, and under the stimulus of the necessity for the greatest accuracy in these factors, as a part of the scheme of Engineer-in-Chief Melville for conducting contract speed trials, we have had the design of an admirable combined chronograph and revolution record by Assistant Engineer Weaver, a description of which appeared in the February number of the JOURNAL.

It was not altogether a result of these trials, but the fact was emphasized by them, that the trials of large fast ships must take place in deep water if they are to have a fair chance to do their best.

A point of practical value which came out during these trials was, that in twin-screw ships no time is gained in turning by backing with one screw while going ahead with the other. In fact, the time is generally a little longer. The diameter of the circle is much less, however, than when the turn is due to the rudder alone.

The greatest value of these trials, of course, and their main object, is the accurate determination of speed and power so that we can tell what it costs to get high speeds and also what are the economical cruising speeds. When the "speed and power" curve begins to straighten out as though it had reached an asymptote, and the usual formula I.H.P. $= KS^3$ becomes KS^4, we find that we must give up the hope of driving our vessel any faster if we expect to make her anything else than a floating machine shop.

Before these trials we were entirely dependent on the results of foreign ships, principally English, as reported through the papers, and it would happen in almost every case that something would be lacking. Now we have every item needed and can go to the data with confidence. One of our young officers, recently deceased after a short but brilliant career, and who had received part of his professional training in England, used to say, "It seems to me that some of you appear to think that English trial trips are conducted principally for the purpose of deceiving American naval engineers." I have never felt that this applied to many of us, but when we compare our results of speed and power with theirs, and can learn nothing as to the standardization of their indicators, we may be pardoned for feeling more reliance in our own work, of which we know every detail.

The *Yorktown's* trials have been of the greatest value in computing, by Froude's Law of Comparison, the probable speeds of other ships. Being a small vessel with a fairly high maximum speed, this method enabled the ratios of higher speeds in larger vessels to be obtained very readily. It may be of interest to note that the speed obtained in this way for the *Baltimore's* maximum horse-power was almost exactly what the subsequent performance of the *Philadelphia* showed that it must have been.

Coming now to the four-hour full-power trials, we have a host of lessons, and first of all is the very point of whether they are worth having. There are those engineers, and of the first rank, too, who say positively that they consider them almost useless. They claim that a four-hour test is a mere "spurt" and is no criterion of what can be done in a continuous run like those made by the great "Atlantic greyhounds." They say, also, that the whole premium system is wrong, because machinery of a given design is capable of only a definite power and no amount of reward can make it exceed this limit.

These points are well taken to some extent, but they overlook one item of the greatest importance. These trials, where every part of the machinery is under great stress, would be impossible but for absolute perfection of workmanship and fitting and the very best adaptation of means to ends. It has

been shown again and again on our recent trials that the last ten or fifteen revolutions per minute have developed defects which had not been suspected. The *Charleston's* air pumps, the *Concord's* feed pumps, the *Newark's* valve gear, the *Vesuvius'* air pump gear, and many others can be cited as instances. Unless the contractor has a powerful incentive, can he be expected to go to the expense of this splendid workmanship and accuracy of adjustment? And again, how would we ever know whether we were setting the proper value for an exacted speed or horse-power? When the horse-powers of the *Baltimore* and *Charleston* were "scaled down" from what it was alleged that their English prototypes could do or had done, it was thought that a fair chance had been given to make the contract horse-power easily. It turned out so for the *Baltimore*, but in spite of everything that skill could do, the *Charleston* could not make 7,000 I.H.P., much less the 7,650 credited to the *Naniwa-Kan*.

The next question that arises is, how long should the full-power trial last? It is alleged, and undoubtedly with truth, that the results obtained on a four-hour run are greater than the averages which would come from a longer period. This is due to a number of causes, the principal ones being the necessity for cleaning fires and the fouling of the heating surfaces. Where the men are under the nervous strain of keeping everything in perfect condition at full power, it is doubtful if they would get enough rest in even an eight-hour interval between four-hour watches. The number of men necessary would be enormous. In all the recent trials of twin-screw, triple-expansion engines, there have been twelve oilers in each engine room, besides other men looking out for the auxiliaries. If we wanted a two or three-day run, we should have to multiply the engineering personnel by three, and as a result we should have more people on board, including the catering department, than the full crew as a war vessel. The cost, also, both for wages and stores, would be very great.

In the English Navy, for some time past, there have been ninety-six-hour trials with moderate forced draft. There is a great deal to be said in favor of these trials, as they give us a

fair idea of what we might expect if our fast cruisers had to do like the fast mail steamers, and I think we might go into this point with advantage.

The point has also been raised, that, inasmuch as a four-hour test is too short to be an endurance trial, a shorter period would do just as well to show the strength and adjustment of the machinery. Just here the recent experience of the *Newark* is valuable. On two occasions the machinery worked perfectly for about three hours, and then a part of the valve gear of one of the L. P. cylinders (a couple of bolts) broke. The same bolts broke each time. Had the limit of the trial been two hours, the first one would have been considered a complete success, and the accident would not have occurred until after the vessel was in service.

These full-power trials may teach us some very important practical points.

Hot bearings are unfortunately only too frequent. How hot can a bearing be run with safety, how long, and what must be done beyond turning on a powerful stream of cold water?

I think we have been free of trouble from foaming in all our recent trials; but, in case foaming does occur, how serious may it be before we are in danger of knocking out cylinder heads?

Low water may occur at any time, even with every precaution, due to some derangement. In boilers under strong forced draft, the water level falls very rapidly. The practical question is how long is it safe to run if we suspect that the highest heating surface, usually the top of the combustion chamber, is uncovered. Many will say, haul fires at once, but there are other considerations. One of these trials costs anywhere from $10,000 to $20,000, and if it is a failure the expense falls on the contractor. Moreover, the people in the fire rooms have pride in not causing a failure through any neglect on their part, and they will always take some chances, so that it would be of the greatest value to know how much danger is involved in taking chances.

During his term as Chief of the Bureau of Steam Engineering, Chief Engineer Isherwood experimented with the Martin

vertical water-tube boiler, and found that it was perfectly safe to run with the water level half way down the tubes, though there was, at least at one end, the full temperature on the tubes and upper tube sheet. We know, too, that in vertical fire-tube boilers the water level is carried some distance below the tops of the tubes.

These cases are entirely different from the one now under consideration, but they suggest experiment and the contribution of such information as any of us may have.

Closely associated with this last point are leaky tubes and feed pumps working badly. The *Concord's* trial was given up because the feed pumps to the forward boilers would not furnish enough water, though the rated capacity of one pump was more than sufficient for both boilers. Was this due to poor arrangement of pumps and pipes, or was it simply a derangement of the pumps which should have been remedied without losing the trial?

Then there are points that come up in connection with faulty working of air and other pumps, journals, &c. Any light thrown on these would be helpful.

One matter that I hope to hear discussed thoroughly is the relative practical merits of the closed fire room and closed ash-pit systems of forced draft. Some of those present have recently been on the trials of the *Newark* and the *Concord*, and have thus had practical experience with both systems.

It is claimed that the men work more willingly with the closed ash-pits and to better advantage than in closed fire rooms, that the boilers are less injured, and that there is less trouble from coal dust. Our officers who were on the trials of both the *Charleston* and the *San Francisco* are enthusiastic in their praise of the closed ash-pit system and consider it greatly superior to the other.

The accident to the *Newark's* valve gear, as well as one or two which have occurred to the *Petrel's* gear, which is also of the Marshall type, suggest considerations as to the peculiarities of this type of gear and whether, when well designed, it is more

subject to accident than the usual gear, the Stephenson link. I believe we have had no accidents with this latter gear.

The change of pitch of the *Baltimore's* screws, with an accompanying increase of power, and the belief entertained by many that a similar change would have benefited the *Philadelphia*, brings up the question as to how to decide on the best pitch for our fast ships; and I trust this will be discussed.

Finally, there are some lessons to be learned in regard to the instruments for getting data and the methods employed. Nothing shows the imperfections of methods like trying them, and recent trials may suggest useful changes in methods or in the items of information usually called for.

The indicator and indicator diagrams furnish a fruitful theme; and while on this point I believe we could profitably consider whether the arrangement of separate indicators on very short pipes is absolutely necessary. Personally, I believe this is a "fad" which has been carried to an extreme, and that where the pipes are of ample size, with easy bends and well lagged, there will be no appreciable difference between the result with separate indicators and one indicator with connections to both ends. When we tried the *Yorktown* at Newport, we had the latter arrangement—the contract trial used the other—and yet we got a greater I.H.P. than on the contract trial. It is true we had more revolutions, and the trial lasted only one hour as against four, but the mean pressures in the H.P. and I.P. cylinders were greater. They were not in the L.P., on account of a very poor vacuum. These mean pressures were corrected for indicator error in both cases.

The point also comes up as to whether the indicator should be cleaned and lubricated frequently, or left alone after first being placed on the cylinder, merely being drained after each card is taken. Engineers of experience might be cited on both sides.

I would also like to get information as to arrangements, by electrical connections or otherwise, for taking all the cards simultaneously by pressing a button. I think this has been done, and the details would be interesting. The advantages are obvious, but the complication necessary may be a serious disadvantage.

I would suggest, Mr. President, that it might be well to send this outline to our members and associates away from Washington, as many of them could give us information of the greatest value on the points which are here merely named. The publication of all these comments would make the most valuable article we have ever had in our JOURNAL.

CHIEF ENGINEER N. P. TOWNE, U. S. NAVY.—In speaking of the trials of new ships, the method of recording speeds which was adopted by Mr. Isherwood on the trials of the Kunstadter screw seems to me to have many points of value. This has been so often described that it is almost needless to describe it again. Suffice it to say, that it is a submerged propeller of such size as to free it from the disadvantages which are sure to follow the use of the patent logs, and which, in their case, it would be difficult, if not impossible, to overcome. This propeller is rigged alongside of the ship, at sufficient distance from it to be free from the current caused by the skin friction, and is connected by gearing to counters on a platform at the gangway or convenient part of the ship. Every turn of the wheel must be registered, if the counters are in order, and in this regard it is almost impossible to make any serious mistake. This propeller has no work to do besides registering its number of turns, which work, in proportion to the surface acted on, is practically the same at all speeds, and any friction, relatively, is reduced to a minimum. Of course there is the friction of the blades on the water, which varies with the speed of turning, but this again is so small relatively that it is not an important factor, or, at least, one for which a rate can be established. The accuracy of its registrations in the trials of the *Nina* were such, that many runs over the measured mile were made without any difference in the number of revolutions, and in turning circles from port to starboard and from starboard to port the difference in the number of registrations was that due to the difference between the circumferences of two circles whose radii differed by the beam of the ship. These trials all took place in smooth water and at a speed not exceeding eleven knots.

In trying the speed of larger ships, and at high speeds, the dif-

ficulty would arise of placing the propeller sufficiently far below the water to secure an uninterrupted working in a moderate sea, and to fasten it with sufficient rigidity to the side of the ship to prevent its springing or carrying away. Of course this latter *could* be done, but perhaps at an appreciable expense of speed of the ship, caused by the resistance of the water passing through the frame work. There seems to me to be sufficient merit in the system which has proved so successful in low speeds to try it at a higher one and on larger ships.

The great center of success in trial trips outside of the accurate recording of the results, appears to me to be the boilers and fire room fittings. While every part of the system of machinery, of course, requires the most careful attention in order to make a success for the contractors, yet, in addition to to this, in the fire rooms we have depending upon the excellence of design and the care of the engineer, the lives of those employed there.

The conditions which obtained in former times in trial trips are now entirely gone and a new order of engineering has sprung up, in which the almost certain loss of life for many men is the result of unskilfulness or negligence. This is most marked in the closed fire room system of forced draft, where there is practically no access to safety in case of any accident to the boilers. With the necessarily complicated system of feed pipes, pumps and valves, and with a fire room filled with coal dust, and amid the roaring of the blowers, it requires a man of steady nerve and a clear head to carry this part of a trial through successfully.

Added to these qualifications he must have a strong confidence in the endurance of the boilers—not in their strength alone, but in that they have other indispensable features of a well designed boiler, among the principal of which is a good water circulation.

What sentiment, besides that which would animate a man to lead a forlorn hope, would lead an intelligent engineer to run one of certain modern marine locomotive boilers through a trial

trip in a closed fire room with three or four inches air pressure?

When, to satisfy the insane desires of those, who, knowing little if anything of the subject, cry incessantly for reduction of machinery weight (in order to load small displacements with heavy armor and batteries), at the same time demanding high speed, this reduction is carried to such extent that the teachings of experience are forgotten or overlooked; then such ships as the *Barracouta*, *Barham*, *Sharpshooter*, *Sandfly* and others can be accounted for. The trials of these ships serve a good purpose only as a warning to engineers not to go too far in reduction of weights, and especially not to attempt to crowd too much heating surface into small boiler shells.

It has lately been found by experiment that a section of tube sheet, having tubes expanded so tightly in it that they could not be driven out when cold with a hammer, expanded sufficiently when heated to a blue heat to allow the tubes to drop out freely. In the case of the *Barracouta* class the tubes have only five-eighth inch between them. With the tube sheet heated as it must be by the fires burning with three inches air pressure in the fire room, the water was drawn away from the tube sheet, the tubes were loosened, and superheated steam was projected over the fires into the fire room among the men, some of whom paid with their lives the penalty of a faulty design. An attempt to avoid a repetition of this occurrence, or to remedy the evil of closely spaced tubes, has been made by covering the tube sheet with a cement made of heat-resisting materials, in which compound gannister enters largely. This substance mitigated the evil to a large extent, not only remaining on the tube sheet to the end of the trial, but gathering ashes which lodged on it from the fires, being two or three inches thick when the trial terminated. It would appear that in a short time the tubes would become plugged with these collections. However, the *Boomerang*, on which ship this experiment was tried, made within 700 of the expected I.H.P., while the other fell more than 1,000 below.

It may be interesting, as bearing on this subject of failures in

the English naval vessels, to make some short extracts from "Engineering" of Nov. 28. Speaking of H. M. S. *Sandfly*, which was sent to the Bay of Biscay in connection with the *Serpent* disaster, and came very near sharing the fate of her unfortunate sister:

"She was assailed by dangers of all kinds, and before one could be met another presented itself. The bilges ran full of water, the pumps were choked, the feed pipes were burst, emitting volumes of hot water which drove the stokers out of the hold, while the navigating officer lost his course and could not tell whether the ship was near the land or well out at sea.

"During this period of trouble the fires had to be drawn four times, owing to minor breakdowns of one kind or another.

"At this time the ship was standing on her head from water in the forward compartments, let in through badly constructed hatches and kept there by choked drain pipes filled with coal dust from the bunkers. Finally the men rushed from the stoke hold exclaiming that a boiler had burst, the whole place being filled with steam, which found its way above and enveloped the vessel.

"Examination proved that instead of the boiler it was the copper feed pipe that had given way and that the feed valves of the boiler had hung up, allowing the water to escape. This was a solid drawn pipe, three and one-quarter inches in diameter; in it was a slit three and one-quarter inches in length, the thickness of the metal not being more than one thirty-second of an inch. The desire to save a few pounds in the weight of the pipe had nearly led to loss of the vessel and crew. The pipes were got out, but could not be replaced, owing to water in the bilge. It was only when the latter was bailed out in Corunna that the job was done."

Three days later, when the *Sandfly* went to the scene of the wreck of the *Serpent*, the flanges on the feed pump gave way and had to be rebrazed.

The editor, in the course of the article, remarks that "It is sickening to read of the lives of our sailors being endangered from such petty and preventable causes."

It is a pleasure to turn from these failures and think how few mishaps have occurred to our ships during their trial trips and afterwards.

In our vessels, although we have had the minor accidents which will almost inevitably occur in machinery of new design, yet there have been no accidents to the boilers, and nothing has occurred to endanger the lives of those on board.

In our recent American designs, while reducing the weight of machinery, the designers have never sacrificed the perfect safety of their boilers or vital parts of the machinery in attaining that end.

I do not call to mind more than one accident or mishap in any of our trials that has caused its discontinuance, and this was the breakage of the radius rod of the Marshall or Bremme valve gear.

This type of valve gear is an English importation, and is most attractive to the designer, but it is a very dangerous thing to handle, although in some places, under certain restrictions and kept within limit, it has behaved admirably.

The great temptation to the designer is to try and make it do just a little more than it will do safely, and there is a limit beyond which no strength of parts will prevent its breakage. When the valve motion is proportioned, there is no safe way of opening the port wider, or of following further, without increasing the lead, which is to remain constant from full gear ahead through all the intermediate positions to full gear astern. This lead can only be altered and the port opening increased by cutting lap from the valve.

But there is one way to secure these results without altering the lead, and that is by throwing the radius rod over further by increasing the travel of the reversing arm. As a result a beautiful curve is made on the board, it works elegantly on the model, and the port is opened to the desired width.

But when driving a pair of heavy quick-working piston valves and overcoming their inertia, which varies in proportion to the square of the number of revolutions, it is found, that the strains

caused by the eccentric and radius rods being nearly in line are more than the metal will stand, and a wreck ensues, no matter how strong the parts may be.

Now the only way to render this gear safe, if we wish to retain the same cut-off point, is to run the radius rod back to its proper position, cut off the lap on the valve and submit to an increased lead, or link up, retain the same lead, and be content with a smaller port opening and shorter cut-off.

As a result, this gear has achieved an unenviable reputation, and few engineers are now using it, preferring to go back to the old and reliable link motion, and throwing out radial gears of all kinds.

MR. ASA M. MATTICE, MEMBER.—Mr. McFarland asks for information on a subject in which I have lately had some experience, viz., the connection of a number of indicators electrically for the purpose of taking simultaneous cards. For a little over a year I have been using a set of six indicators with an electric attachment made from my designs, and, as far as I have been able to learn, this is the first attempt in this direction. The apparatus is very simple, and may be briefly described as follows: To the underside of the piece which joins the steam cylinder and paper drum is fastened by two small screws a light arm carrying a pair of small electro-magnets. The bobbins of these are covered all over with hard rubber to protect the insulation from steam and water. An armature for the magnets is carried on the sleeve surrounding the steam cylinder on which the parallel motion is mounted, and is so adjusted that when the armature is nearly touching the magnets the pencil touches the paper, but when thrown back by a spring the pencil point is about a sixteenth of an inch away from the paper. The armature is not rigidly screwed to the sleeve, but is on a collar surrounding it, the working connection between the two being made by a light spring with its end pressing into a V groove. This gives a sufficient hold to press the pencil up to the paper, but gives way easily when the pencil bar is thrown back by hand for the purpose of putting a new paper on the drum. After once being adjusted no further adjustment is necessary except to see that

the pencil point is not more than $\frac{1}{16}$ inch away from the paper in normal position. I keep the apparatus permanently on the indicators, which are carried in boxes of the usual size, with only some slight alterations to their internal arrangements. I use four cells of the Gassner dry battery, which are fitted in a box of about the size of a box for two indicators. I find three of the cells sufficient to work the six indicators under ordinary conditions, the fourth cell only becoming necessary when indicating cylinders where more than about 100 feet of connecting wire is necessary. This battery requires no attention whatever, and has not perceptibly diminished in strength since I have had it in use. If the circuit is kept closed for any length of time the strength of the current decreases rapidly, but recovers quickly when the circuit is broken.

I have found this method of working indicators of the greatest convenience, as it reduces the number of persons necessary in making a test, and at the same time takes the cards from all cylinders without any doubt of their being taken simultaneously. I think that similar apparatus could be used on board ship to great advantage. On trial trips the number of engineers assigned to indicator work could be reduced, while the senior engineer would have it in his power to indicate every cylinder in the ship at the same instant by merely pressing a button. The same could be done in regular service, giving the engineer of the watch an opportunity to take a simultaneous set of cards from every cylinder of main and auxiliary engines without assistance from anybody. On board ship the wiring could be permanent and attached to a stationary battery. All that would have to be done in addition to the usual work in getting the indicators ready would then be to attach the wires to the binding posts of the instruments. After getting the papers all on, and the indicator cocks open, the engineer could take his station where he could read the gauges and counters, and take his cards at the instant he desired.

During a recent ten hours' test of a triple-expansion engine in an electric plant, I had all six indicators in use, and took all the cards myself, taking a set every twenty minutes, besides super-

vising the work of five assistants who were engaged in other parts of the work; and during one hour I took three extra sets, or at the rate of a set every ten minutes, besides making the tour of the entire plant every twenty minutes. With the ordinary methods this work would have required an operator for every cylinder, at any rate if the cards were to be taken "simultaneously." (?)

I cannot agree with Mr. McFarland that the use of two indicators on a cylinder is a "fad." Apart from the question of correct pressures I prefer to use two indicators on account of the greater convenience, using them directly connected, without bends, and in a horizontal position generally. Besides, with compound or triple engines with varying load and sensitive governors, cards cannot be taken, where only one indicator is used on each cylinder, sufficiently near together to permit a combined card to be made which will properly represent the action of the steam. As to the question of pressure, apart from my own experience, I know that some very level-headed engine builders, when they give a very close guarantee of duty, will not permit a bend in an indicator pipe used during the test, and as the cost of changing the connections, if not rigged that way for the customer's use, comes out of their pockets, they must have some reason for their action.

As to cleaning and lubricating indicators, much depends upon circumstances. During a recent ten days' mill test, I began with my usual practice of cleaning the indicators once an hour. I soon found that unnecessary, and came down to cleaning them only at the end of each day's run. In this case the engines were run non-condensing, all the exhaust steam being used for heating, &c., and so the boilers were kept free from grease, and as the feed water was very clear, there was no dirt worked over into the cylinders. In other cases, where the water was used over and over again, and a cheap oil used in the cylinders, I have found it necessary to clean the indicators for every card. The oil which the indicator makers furnish with the instruments is very nice to look at, but I find it worse than useless in an indicator at high pressures. I prefer the very best grade of light

mineral cylinder oil, which, although it costs nothing compared with the fancy oil, keeps the piston lubricated without decomposing with high steam. Care should be taken, however, to use a pure mineral oil, and not one mixed with animal or vegetable oils.

I had intended to prepare a sketch of my electric indicator attachment, but have not found time to do so. If the readers of the JOURNAL should think the subject of sufficient interest, I may do so at some future time.

MR. HORACE SEE, ASSOCIATE.—The breaking down of a piece of mechanism of a particular type is not a sure indication that this type is more subject to accident than another employed for accomplishing the same purpose. The cause of accidents generally can be found through the medium of investigation. It may be hid in bad design, workmanship, material, or in the negligence of the operator. The accidents which befell the machinery of the *Newark* to my mind were not an exception, and are traceable to a definite cause. They were not only confined to one engine, but also to the gear of one cylinder of that engine. It seems to me perfectly reasonable to suppose, in view of this fact, that the length of the particular radius rod which broke its bolts on the two first trials may not have been the same as that of the one which escaped injury, or that during the first trial the want of oil on some parts connected with this gear may have caused the surfaces which had not received the proper attention to seize, and thereby bring upon them undue strain. If the assumption is correct, the type of gear is not to blame for what happened. The Stephenson link motion, which, like the Marshall, is of English origin, is just as liable to accident, if the link is thrown out of its proper position, as the radius rod of the radial gear. It also suffers from neglect. When such accidents have happened, they have not taken away any of its deserved merit. Nor should the Marshall gear, which possesses not only superior advantages, but has given equally good results as the Stephenson link, be condemned for what is just as liable to happen to its predecessor if treated in the same way. An intimate acquaintance with the Marshall gear will reveal how great are its

merits. Its prominent features are compactness, fewness of parts, joints of a shape that can be produced in the best manner and at the least cost, of superior durability if properly proportioned, permitting the greatest accessibility to all parts of the engine, and what is most important, the attainment of maximum horse-power. The engines of the *Newark* are an eminent example of all of those characteristics. The possibilities of the last one were exemplified on the trial by showing a collective horse-power of 8,868, a performance equalling that of the best.

No valuable conclusions about the performance of a vessel or her machinery can be reached if the instruments and methods employed are unreliable and the data incomplete. The performance of the screws of the *Baltimore* came under this head. Whether the original pitch was right or wrong can not be gained from the report of the trial made with it. The distance run was determined from the reading of a patent log, the accuracy of which can not be relied on at the speed at which the vessel was being propelled. The engines also were not developing their full power, one being crippled by the closing of its throttle on account of "a good deal of priming" in the boilers which supplied it with steam. The priming no doubt was caused by the presence of salt water, pumped into the boilers to make up for the loss of the fresh, which took place whilst the vessel was lying at the break-water. It is also probable that the other set of boilers was from the same cause not working at its best. The coal consumed each hour was much less on the first trial than on the second. The pitch of the screws certainly had nothing to do with this. The management of the fires and the intensity of the draft were without doubt the prominent factors. A comparison of the reports of the two trials will show that on the second very nearly 3,000 pounds more coal were burnt each hour than on the first:

I.H.P. of all machinery, first trial, 9,548; second trial, 10,064. Coal used per hour, first trial, 27,383 pounds; second trial, 30,353 pounds. Coal per I.H.P. per hour, first trial, 2.86 pounds; second trial, 3 pounds.

I conclude that the weight of coal was obtained in the same way on both trials, and that it is approximately correct. We cer-

tainly can assume that it is nearer the truth than the speed of the vessel recorded by the log. It will be noted in the above table that the coal consumption very naturally increased with the horse-power; also, that the lower power was secured with a less consumption of coal per horse-power per hour, due, no doubt, to slower combustion. If the reported coal consumption is anywhere near right, it is safe to assume that the boilers were not working at their utmost on the first trial, and that the power developed was not what the engines were capable of doing; consequently, that the performance of the machinery was not a complete one.

In order to determine whether one propeller is superior to another on the same vessel, the trial should be one made over a carefully measured course, and not a run with the log, which gives a variable length. The trial should be a progressive one, if possible; but if a run at the extreme speed is made, the power developed by the engine or the coal burnt should be nearly the same during each. The depth of water under the vessel also has a great influence over the revolutions made, and from them over the speed obtained, so that the run should be made over the same course, and if possible, at the same stage of the tide. The engine should be permitted to use all the steam that the boilers are capable of generating. If all of these conditions exist on the trials, then we should be able to determine which wheel drives a particular vessel at the highest possible speed, and consequently, which one gives the best results.

Passed Assistant Engineer Howard Gage, U. S. Navy.—In regard to air pumps: To my mind a smooth-working, independent air pump, that is, one that will run without a man standing by it all the time, and that will not require a governor, can only be obtained by adding to the load given by the air pump some uniform load, such as that given by the circulating pump. As a proof of this we have the *Dolphin's* air and circulating pumps, the *Concord's*, and the combined air and circulating pumps for the auxiliary condensers of the *Philadelphia* and *Newark*. An auxiliary engine of any kind that requires the constant attention of one man to keep it running is not fit for a

man-of-war, and to my mind some of the independent air pumps are very much such machines.

In regard to the indicators: Some of the springs have very slight corrections, others very great. Why not get a set of springs with slight corrections and use them on these full power trials, without troubling about corrections at all? The horse-power would be as correct as the speed. Then, for scientific experiment, and to find the true relation between power and speed, conduct progressive trials, and then bring in every correction possible. The full power trial, to my mind, is a commercial affair, and it does not make so very much difference what the standard of payment is, as long as it is fair, and is something that can be obtained with a reasonable degree of accuracy.

The strength of parts of the engine as shown by the four hours' trial, is very much like the strength of a boiler as shown by the pressure test. Both stand it, but it is not the point at which either should be worked, if a proper margin of safety is to be allowed.

Assistant Engineer Charles A. E. King, U. S. Navy.—I am of the opinion that one indicator, properly and accessibly placed, and connected with the ends of each cylinder by well lagged pipes of sufficient size, will yield more accurate results than the present plan of using an indicator for each end, connected by short pipes. That there will be no appreciable loss of pressure at the indicator by the former plan, I am convinced, if the necessary and usual precautions of thoroughly draining and properly heating the pipes by blowing through them are duly observed before each card is taken.

The system now employed of indicating the engines of our new ships renders the value of the cards taken of little consequence as simultaneous observations. An improvement in this respect would follow the adoption of the plan proposed. The chance of inaccuracy from faulty adjustment of the instruments would be lessened by reducing the number of indicators used, and the increased accessibility of position rendered possible in many cases by this arrangement would lessen the proba-

bility of grave personal error. That accuracy suffers from personal error in the adjustment of the indicator, the string, the pencil point, and in the manner of applying the pencil to the paper, is patent to all who have used the instrument. And it will be seen at once, that if the instrument is so placed as to cause great inconvenience to the observer in its manipulation, the chance of inaccuracy in the diagram traced becomes great. The officers who were stationed at the inboard ends of the I.P. cylinders on the recent trial trips of the *Newark* will appreciate, I am sure, the truth of this statement. The arrangement of the indicator attachments on that ship may be cited as an example of a system which should, by all means, be avoided.

My experience has taught me that with steam of 140 pounds pressure and over, used by engines of three expansions, the action of the pistons of the indicators of the H.P. and I.P. cylinders is improved by their removal and cleaning and oiling once an hour, but that this is unnecessary with respect to the indicators of the L.P. cylinders.

The tables of corrections to be applied to the pressure ordinates, as found from the diagrams of a given indicator, are, I believe, determined by experiments with the indicator and the proper spring previous to the trial during which the instrument is to be used. Would it not be a step in the direction of accuracy to make similar experimental tests immediately after the trial, throughout the range of pressure employed, and adopt as the true corrections the mean of the two sets of corrections determined?

As a commentary upon the accuracy of the indicator now employed, as regarded by at least one of the great engine building firms of the country, I will say that upon asking an engineer who is very intimately connected with a prominent company, why a certain type of indicator, in which I have little confidence, was to be employed upon a recent trial trip, I was informed that the type of indicator in question would give a "*greater horse-power than any other on the market.*"

PASSED ASSISTANT ENGINEER H. WEBSTER, U. S. NAVY.—One of the most important questions involved in the full power

and full speed trials of the Navy Yard built ships, *Maine* and *Texas*, will be the personnel of the force in the engine room and fire room; for unless the men composing those forces are capable of performing their duties of every kind without supervision, the best efforts of designer and builder will come to naught. This applies especially to those concerned immediately with the feed system of the boilers, and with the oiling details of the main engines.

Naturally the data will be taken as heretofore by a corps of skillful and intelligent Engineer Officers of the Navy, but the details of actually running the engines must be attended to by a class of men hitherto unaccustomed to exercising individuality, men who obey well, work faithfully under the eye of an officer, but who, from long and disastrous experience, are unfit for the exercise of actual authority.

Not only will the quality of the enlisted men upon which will depend so much be of a very moderate average, but the number to be procured will be quite a serious matter with which to contend, and unless special efforts are made in advance, the Bureau of Steam Engineering may find itself handicapped from the very start, as compared with the large ship and engine building firms with which it has to compete.

It may be that the builders or contractors propose to see that their machinery is tested by their own men, in which case the question simplifies itself materially and the result can be anticipated.

In view of the contingency here outlined it would seem as though the time had come when the Navy should be furnished with a body of enlisted men numerous enough for the requirements of the largest ships, competent to perform all the duties of manipulation during the trial of the engines of a ship, and especially reserved for that purpose. It is only thus that results from Navy Yard built ships can be obtained at all comparable with those effected by the skilled labor at the command of the civilian contractor and builder.

As an illustration of the point proposed here, the case of the trial of the *Charleston* may be adduced. During her successful

trial of August, 1889, the oilers and others in charge of the various parts of the machinery were no less than licensed engineers in the merchant service, and in more than one instance a deep-sea license as first assistant engineer demonstrated a man's fitness for any duty assigned. The natural result of this was that the men in general charge of the trial had naught to do save to keep a sharp lookout on everything about them; but no orders were given, for each subordinate knew as much about his duties as could be told him.

Where, in the Navy, are there to be found enough enlisted men of the right kind to secure the machinery of the *Maine*, for example, against damage, and at the same time to insure the best results from the talent of the designer and the skill of the builder?

Passed Assistant Engineer G. W. Baird, U. S. N.—Concerning the feed pumps of the *Concord*, I think the failure of the forward one was due to the fact that the water did not reach it. When water is in motion it tends to keep its direction, and will naturally flow in the direction of the nearest outlet, *i. e.*, in this case, to the nearest pump. My own experience is that, where two feed pumps are employed in the same circuit, one will usually give trouble; I have invariably found that I had less trouble when one pump was out of circuit. The *Concord*, I believe, has an independent feed pump in each fire room, and both of these pumps draw water through the same pipe. I therefore suppose the after pump, which is nearer the hot wells, robs the forward pump. Assuming that twenty pounds of feed water was used per I.H.P., one of those pumps would have fed the entire plant of boilers when running at a piston speed of but 100 feet a minute, had it been in order, and had the water reached it. I feel sure, however, that the careful people of the Quintard Works were assured that the pumps were in order. This failure was, therefore, no fault of the pumps, but of their supply.

I think that we are much in need of a series of trials, preferably dock trials, of one or more of the new vessels. These trials should be conducted and the expense borne by the Government. As nearly as we are able to estimate, it is costing us

three pounds of coal for every horse-power we obtain on these forced-draft trials, when the vaporization of the boilers cannot be above six pounds of water per pound of coal. But we do not know just what this is, nor can we know until a series of tests is made. We should first test out the boilers with different rates of combustion, and ascertain the vaporization in each case, and also rate the foaming. The results would, I have no doubt, enable us to better proportion our boilers. We should make a serial test of the engines, the auxiliaries as well as the main engines, which would also probably lead to better proportions. My impression is that we have reached the highest economical steam pressure and ratio of expansion; perhaps we have passed them. About thirty years ago, a test made on an engine of the Navy proved that we were employing too great a ratio of expansion with the engine as then proportioned. This test led to a design of engine that could utilize the higher ratio of expansion economically. Since the War of the Rebellion Congress has given us very little money for experimental purposes, and we have been obliged to copy largely from foreigners—their mistakes included—greatly to our own embarrassment.

ASSISTANT ENGINEER W. P. WINCHELL, U. S. NAVY.—In reply to Mr. Baird I would say that the *Concord* has two vertical duplex feed pumps in each fire room. I was in the forward fire room on the trial, where the main difficulty with the feed is said to have occurred, and I must say that the pumps have received more than their share of the blame for the failure to make 3,400 I.H.P. The real cause was defective firing, mainly in the after fire room.

Comparing the coal and ashes of the two fire rooms, it is seen that the forward boilers were doing most of the work and burning about one-third more coal than the after ones. So it seems rather unfair to make a scapegoat of this fire room. While there may have been some trouble with the feed pumps, owing to their having to lift the water by suction from the feed tank, it was not until the trial was over that this trouble grew so great that it could have been made responsible for the failure.

The water during the whole trial was carried unusually high;

at no time did it get below the third gaugecock. I had noticed no difficulty with the feed, and when the trial was over, I asked the water tender if he had had any trouble with it; he said "No." Two days later I again asked him the same question and got the same reply. Had the full pressure been carried right along, it is possible that the pumps would not have fed readily, but the pressure fell gradually, until at the end of the trial it was some forty pounds lower than at the beginning. It seemed to me that the fires were carried too thin for the high air pressure (three inches or over most of the time). The shaking grates were not worked as often as they should have been. There was the greatest difference observable between the spirit of the firemen on this trial and that of the Cramps' men. The latter firm seems to be blessed with a fine lot of "hustlers," and they certainly get all the power out of the machinery that is in it. The *Concord's* firemen seemed, with one exception, to take no personal interest in the trial.

Having been in the fire room on the three trials of the *Newark*, I had a chance to compare the two systems of forced draft. As regards temperature, both were cool enough, since both trials were made in cool weather. In hot weather the closed fire rooms will undoubtedly be found more comfortable. The *Newark's* were entirely too cool for comfort, the temperature at one time getting as low as forty-five degrees.

Water was run on the blowers to keep the bearings cool, and of course it was well distributed over the fire rooms. It was very cold and very wet. Climbing up to the blower platforms was like breasting a heavy gale in mid-winter. The drops were thrown out with such force that they seemed to go right through one and come out the other side uninjured like an armor-piercing projectile. After some time the blowers were fitted with canvas screens that held the water and banked it up until some shivering wretch got directly below. He had a sympathy for the rocks under Niagara after that.

In warm weather it will probably be found that the thermometers above the blower platforms will indicate the highest temperatures of the fire room, though on the *Newark* it was as cold

there as elsewhere. There was no trouble with flying coal dust, as the wet had also subdued its aspiring spirit. I think that even with dry coal very little dust will be blown around, except when the blowers are first started. It is a good plan to wet down before starting them.

One advantage that the closed fire room has over the other system is that the grates can be seen at all times, and any melting bars can be cooled by playing on them with cold water. On the first trial of the *Newark* three or four threatened to come down, but were kept from doing so by playing a hose on them occasionally. Had the ash-pits been closed the trial might have been a failure from this cause. The *Concord's* contractors said they could not use Pocahontas coal on this account, as it caked on the bars and melted them. Their boilers have patent revolving grate bars.

The Cramps use this coal on all their trials, and certainly get good results with it. It is first put in the front of the furnace, and banked up nearly to the crown sheet. When it is all ignited and begins to cake it is pushed back evenly over the grate with a hoe, and the slice bar is used liberally afterwards to break it up and prevent caking.

The firemen on the *Newark* were not overworked. The boilers easily furnish all the steam the engines can use. On the successful trial, for 4½ hours, the minimum pressure was but 4 pounds below the maximum. Steam pressure was regulated by the blowers. At the end of this trial the engines were performing better than at the beginning; the index of the steam gauge seemed nailed at 161 pounds; there had been no indication of leaks, foaming, or defective feed, and I believe the same set of men could have gone on for another 4 hours had any emergency required it and the boilers continued doing as well as before.

One point that may be worthy of notice was brought out on this trial. When a ship lighted by electricity is to be run at full power, it is well to have lanterns burning at important places, such as the gauges, blower platforms, wing passages, &c., or at least have the lanterns within easy reach for use in case of short circuit, breaking wire, or other derangement to the electric light

plant. For eight minutes, on the first trial of the *Newark*, the wing passage and No. 2 fire room were lighted only by the furnace fires. Such a failure when the water is low, or when any slight accident occurs, might necessitate slowing down or stopping, if it were productive of nothing worse.

Regarding the feasibility of weighing the coal used on trials, I think the contractors would find it easy to do so if a clause in the contract required it. Naturally enough they do not want to hamper themselves and throw extra work on the coal-heavers when the contract does not require it.

The contractors of the *Concord* took the trouble to weigh and bag the coal to be used on the trial, and a careful account was kept of the number of bags emptied. In a ship with open fire rooms this is probably the best method, as the extra work of weighing is all done before the trial begins, when there is plenty of time to do it accurately.

On the *Newark's* coal consumption trial of four hours the bunkers were not half full, and but one coal heaver was put in a bunker for the first two hours; after that he had another to assist him. While but one man was there he had to shovel the coal from the forward part of the bunker to the middle and then again to the bucket, wait until it was weighed, dump it, and replace the bucket on the scales; thus doing at least twice the work he did on the trial when the bunkers were full and but one handling of the coal was necessary. Besides the disadvantage of an almost empty bunker, the trial started with only four buckets on the fire room floor, and for the first hour it was lively work to keep ahead, as the fires were all being built up. After the second man came there was no difficulty, and had the bunkers been full, as they usually are at the beginning of a trial, one man could have done the work, especially if plenty of coal had been got out before the actual trial began. More coal was probably burned per square foot of grate on this test than on the contract trial, for since the engines could use all the steam furnished by the two boilers the latter were forced more. The air pressure was slightly greater also, and there was no trouble with the blowers, which ran for the greater part of the time without water.

The coal was weighed on small platform scales placed just inside the bunker doors. After trying various methods we adopted the following as giving the quickest and most accurate results. A bucket was filled with average coal and carefully balanced; the shifting weight was then clamped in its position, and all succeeding buckets were made to tip the scales at the same weight, coal being added or scraped off as required. The coal heaver became expert after a little practice, and could gauge the amount required to a nicety.

Assistant Engineer S. H. Leonard, U. S. N.—In regard to closed fire rooms, I can say this, that the arrangement on the *Philadelphia* was such that the air shot down over the bunker door, and as a consequence there was a continual whirlwind of coal. Goggles were used, but afforded only slight protection to the eyes, as they soon became clogged with coal dust, and had to be worn over the end of the nose, where, while they did not interfere with seeing, they interfered just as little with the coal dust and pebbles that filled the air.

On the *Philadelphia* there would have been no difficulty at all, in my opinion, in measuring the coal during the trial. There was plenty of time, and, in this case, plenty of steam. It was simply a matter of speeding up the blowers a little whenever the steam dropped. At the time of the coal consumption trial the bunkers were but partially full, and the bunker doors wide open; yet the air pressure was greater than during the speed trial, showing little or no loss of pressure due to escape of air through the bunkers.

Assistant Engineer W. H. Chambers, U. S. Navy.—In regard to the effect of a closed fire room on the men, I should like to say that those in the fire room in which I was stationed during the trial of the *Philadelphia*, did not seem to be concerned as to possible accidents. The men stationed at the blowers complained that their position was a trying one. The temperature on the platforms where these men had to be most of the time to oil and regulate the blowers averaged 124°, while in the lower part of the fire room it averaged only 101° Fahr.

It is natural that the men on a contractor's trial should do

well, as they are selected for the purpose, are interested proportionally with the contractor in the premium offered, and, the duty being temporary, are anxious that it shall be successful in order to have it over.

In regard to the fire room data, the arrangement of lights and instruments was not such as to insure accuracy, and, as Mr. Leonard has just said, the necessity of the use of ill-fitting goggles added largely to the general inconvenience.

I agree with Mr. Leonard in not being able to see any good reason why the coal used on the regular trial of the *Philadelphia* should not have been measured. A strong objection was made by the contractors to bagging the coal or measuring it as it came from the bunkers on account of the inconvenience of so doing. In each fire room there are four bunker doors, two into the athwartship bunker and two into the fore-and-aft bunkers, so that a portion of the bunkers, sufficient to hold the coal required for four hours, could have been temporarily bulkheaded off at little expense, and the coal remaining at the end of the trial measured.

The coal consumption trial with two boilers under forced draft was of too short duration to be an accurate comparison with the official trial.

Assistant Engineer W. Strother Smith, U. S. Navy.—As showing whether or no the length of pipe in indicator connections has any great effect upon the pressures recorded, the following may be of interest: On the *Galena* the pipes were so arranged that the cards could be taken at the ends of the cylinders, or both inboard and outboard cards could be, and ordinarily were, taken at the inboard end. For the sake of experiment I have taken outboard end cards simultaneously at the inboard and outboard ends of the cylinder, using tested indicators. Yet, though I took many sets, I have never found any appreciable difference. The experiment was so crude, owing to lack of fine instruments and slack gear that I have never given it out; still I firmly believe that a long pipe makes no difference.

Assistant Engineer C. A. Carr, U. S. Navy.—There has been some difficulty in determining the amount of coal actually

burned on full-power trials. By the method used by Chief Engineer Ayres on the coal consumption trial of the *Newark* the coal was weighed as it went into the fire room, and what was left on the floor plates at the end of the trial was weighed back into the bunkers. With two platform scales to each fire room the coal could be weighed faster than it was burned. This requires additional men to tally coal, but there is no risk of a failure to secure reliable results. If the coal for the trial is bagged or weighed into the bunkers by itself, the difficulty is that a partial trial before the successful one may make it necessary to use other coal, and consequently necessary to estimate the amount burned. This was the case on the trials of the *Bennington*.

The taking of indicator cards, as nearly as possible perfect, is the most important part of a horse-power trial, and is a point which has not always been given sufficient attention. Parts of several cards should not be shown, the lines should be distinct, and at the same time there should be as little friction as possible between the pencil and the paper. This will be the case if the lead is soft and sharp, the pressure light, and the paper smooth. Care in the selection of leads and blank cards will, I am satisfied, make more difference in the result of a horse-power trial than would be found between any of the several methods of applying indicator corrections.

The general effect of friction of the moving parts of an indicator is to increase the area of the card by retarding the pencil while tracing the expansion and compression lines. A rough spot in the cylinder of an indicator might cause a very marked irregularity in the expansion line. This was the case with one of the indicators I used on the after H.P. cylinder of the *Newark*, and the appearance of the cards taken by this indicator was improved by keeping the piston well lubricated. Several of the indicators used on the *Newark* were not in a first-class condition, the piston and cylinders being scored in places, and there is no doubt that they recorded pressures nearer the true ones with lubrication than they would have recorded without it. On the *Newark* the ordinary cylinder oil was used on all the pistons of all the indicators. It might have been better to have used a lighter oil on the I.P. and L.P. cylinder indicators.

In making the tests to determine indicator corrections the oil furnished with the indicators should be used. It is probable that care in regard to this would make the conditions of the tests at the New York Navy Yard agree more closely with the conditions under which the indicator is working aboard ship.

ASSISTANT ENGINEER EMIL THEISS, U. S. NAVY.—As to the advisability of lubricating the pistons of indicators, my experience on the *Newark* led me to conclude that with the high pressures of steam occurring in the H.P. cylinder of a triple-expansion engine and an indicator piston tight enough to prevent steam leakage, oil should be used at frequent intervals. With a rather loosely fitting piston, lubrication is unnecessary. Besides correcting the pressure ordinates of indicator cards, the indicator motion should be carefully examined to make sure that the motion of the drum corresponds exactly with that of the piston, or else a scale of corrections applied in the length of the card. Mr. McFarland asks for information on one point which has lately received attention. I allude to the exposure of heating surfaces to the furnace heat due to shortness of water. Under "Notes," in this number of the JOURNAL, will be found an abstract of the report on experiments conducted under the auspices of the Manchester Steam Users' Association, which will be interesting reading in this connection.

The duration of forced-draft trials is a matter about which there is much diversity of opinion and of practice. The period ranges from two hours to six in different countries. A similar diversity exists in the matter of choosing the crew to run the trials. In the German naval service the duties are all performed by the regular crew of the vessel; in other countries these devolve on men more or less trained for that specific purpose. The full-power trials should be supplemented by trials to establish the coal consumption at various speeds and with varying conditions of bottom and varying conditions as to wind and sea; also the most economical rates of speed under these conditions. Not until these points have been established and put in shape of a reference table for use on board the vessel, should the latter be considered ready for a cruise.

X.

PRESERVATION OF MARINE BOILERS.

By Assistant Engineer S. H. Leonard, U. S. Navy.

To the sea-going engineer the condition of the boilers under his charge is a constant source of anxiety, and justly so, for on them all other parts are directly dependent. As a consequence there is no work in the engineer's department which will count to greater advantage than constant and intelligent care in fighting the forces of deterioration, either mechanical or chemical or both, which commence immediately the boiler is lowered into the hold of the vessel.

Of the two forms of corrosion, internal and external, the latter is the one the great percentage of boilers suffer from the most; and in fact if they could be kept perfectly tight, so that there was no leakage at rivets, seams or tubes, internal corrosion, except in rare instances, would cause but little trouble, and the life of the boiler would be doubled and trebled. However, as the perfect boiler is yet to be built, the best that can be done is to check all leaks as soon and as effectively as possible.

Unfortunately the exigencies of the naval service in many cases are such that the boilers are kept under steam for many days continuously, thereby preventing repairs which should be made at once, and as a result, when the opportunity does come, the fault has become greatly aggravated, requiring much greater skill and labor to make it good, if indeed it can be successfully repaired at all.

Herein lies the difference in the length of life of boilers in the naval service and those of the mercantile marine, where there is much greater regularity of working; while the former last from six to nine years, those in the merchant service are kept in effective repair for ten to twelve and even fifteen years.

In placing boilers in the ship care should be taken that the

saddles do not come in line with the circumferential seams, as these latter at the bottom of the shell are very liable to leak. A longitudinal seam at the bottom of the shell is very liable to be a constant source of trouble.

The felting or boiler covering is better left off for about one-third of the circumference on the lower side, thus allowing ready access for inspection and repair where it is generally most needed. This portion of the shell should frequently receive a coat of paint, which should be applied before the boiler becomes thoroughly cold after fires have been hauled. This will insure painting on a dry surface, which will not be the case at any other time after the boiler has become cold, as sweating very soon commences, and is never absent, at least to some extent, so long as the boiler remains unused. I have found black a very suitable color for this portion of the shell, for the reason that any slight leak is readily traced to its source from the small red line of iron rust showing plainly on the black surface. Either Dixon's graphite paint, lamp black and boiled oil, or black lead ground in oil, answers the purpose very well.

The most common sources of external corrosion in marine boilers are, exposure to leakage from joints, tubes or fittings, dripping from mountings, moisture arising from the bilge, and sweating. Serious sources of corrosion of the heating surfaces result from neglect to thoroughly clean furnaces, tubes and connections of ashes and soot before they have an opportunity to absorb moisture, which they will do shortly after they become cold. Ashes collecting in cracks or joints between bridge-walls and furnaces after fires are hauled soon absorb moisture, and rapid corrosion of furnace plates is the result. Wet ashes about the front of the boiler are especially destructive. In cleaning furnaces a half dozen bars taken from each will allow the ashes to be thoroughly removed from bearers and bridge-walls.

Leaky seams and rivets should be caulked at the earliest opportunity; in some cases in old boilers where the seam is beyond caulking, and is on or near the shell bottom, the application of a dose of cement will often greatly check or stop it. Take about equal parts of Portland cement and fresh, sharp sand, mixing

with fresh water to the consistency of mortar, and apply to the faulty seam from the inside of the boiler. Wherever the cement is to be applied the metal should be first thoroughly cleaned with lye to remove any grease or sediment. If leaky tubes are not attended to at once, a thin layer of rust will form between the tube and sheet, rendering it a difficult matter to make the tube tight ever after. If the tubes become thin and weak from repeated expanding, the only remedy left is, after a final expanding, to fit ferrules, driving them in solidly. The writer's experience with cast-iron ferrules has not been altogether satisfactory. Some of the tubes in a Scotch boiler in the ship on which he last served were fitted with cast-iron ferrules, but the tubes remained tight only a short time, and it finally became necessary to remove these ferrules and substitute others of wrought-iron, after which no further leaking occurred. Adamson rings are sometimes annoying from the persistence with which they will leak, and for this reason, where the leak develops, the seam should receive very careful caulking.

The only effective method of checking leakage around screw stays with riveted heads is by upsetting; that is, with a heavy sledge held firmly against one head, several sharp blows with a quarter hammer on the leaking head will fill out its threads into those of the sheet, making it perfectly tight. Caulking the heads is a little worse than useless. Internal caulking is an evil, from the fact that it is often the cause of serious grooving of the plates. It is never necessary in a well made boiler.

Considering the question of corrosion chemically we find that dry, pure oxygen alone has no action on iron or steel, moist oxygen acts only very slowly, and pure, dry carbonic acid has no action; but when these gases are mixed in the presence of moisture, as in the hold of a vessel, rusting or corrosion rapidly follows and goes on at an increasing rate. To abate this evil, all possible means should be taken to drive out of the boiler compartments as much of the moisture as possible. When the weather is dry much benefit might be derived from running one of the blowers moderately in each compartment. If the boilers are not to be used for some time, an auxiliary steam-pipe might

be tapped, and a line of piping led into the lower manhole of each boiler, the boiler otherwise being closed so as to retain the heat, the pipe thence leading to the trap. This method the writer used on the boiler of the U. S. S. *Fish Hawk* with excellent results; the interior of the boiler remained dry and there was no external sweating excepting for a foot or two from the back head beyond the influence of the heater pipe. With this method care should be taken that there is sufficient pipe to not only raise the temperature of the *air* inside the boiler, but also to raise that of the *shell* slightly above the surrounding external air, otherwise sweating of the shell will go on inside as well as outside. An excellent method of checking internal corrosion is the introduction of a barrel or two of quicklime into the empty boiler and then closing all plates, the lime absorbing the moisture and effectually checking the corrosion.

Of the different forms of internal corrosion, pitting or honeycombing is the most serious, and it first made its worst attacks in marine boilers at the time of the introduction of the surface condenser. Of this form of corrosion it has been truly said, that the one characteristic that was uniform in relation to it was the want of uniformity with which it occurred. It is certainly most capricious in its attacks, be it in the same boiler or in a battery working under exactly similar circumstances. It may be found on every plate or on only one plate of a boiler, generally below the water-level, although at times above it. The braces are sometimes the only parts affected, while again these latter are free and the plates are seriously attacked. Of a half dozen boilers made of the same brand of plates, in the same shop, and then worked side by side, one boiler will be seriously affected by pitting, the remainder suffering very little, if at all.

Unlike ordinary corrosion, pitting is marked by sharply defined edges, resulting in holes and patches of from $\frac{1}{4}$ inch to 6 inches or more in diameter, and often assuming very irregular shapes, the depth of the pitting varying from $\frac{1}{32}$ inch to $\frac{1}{4}$ inch or more. Examples of this action are shown at *C* and *D* on the plate; *C* was cut from the bottom of the shell of a boiler which had been doing duty in a tug boat; some of the pits are nearly

$\frac{1}{4}$ inch deep, while others are only $\frac{1}{16}$ inch; the remaining surface of the plates, even close to the deepest pits, was but very little affected by corrosion; *D* was cut from the bottom of a steam launch boiler; the plate which was originally $\frac{1}{4}$ inch thick was reduced in some places to $\frac{1}{16}$ inch bare.

The action on tubes is shown at *A*, which is a steel water-tube taken from a marine boiler after $3\frac{1}{2}$ years' service; the steel in the immediate vicinity of the hole was but slightly corroded.

Sometimes this form of corrosion acts in a somewhat different manner, the plates becoming indented by very small holes close together, somewhat resembling in appearance the wood sheathing of a ship which has suffered from the effects of the teredo; this form of corrosion, termed honeycombing, is shown at *E*, which was cut from a furnace of a land boiler; the plate, which was originally $\frac{1}{2}$ inch thick, was honeycombed to a depth of $\frac{3}{8}$ inch, the holes appearing as if drilled; this action was supposed to be the result of using water from a coal mine, and it was the cause of a serious explosion. In this case the bottom of the boiler and crowns of the flues were the parts most seriously affected. Perhaps the most satisfactory method of dealing with this form of corrosion is the application of cement. Where it is applied to heating surfaces, the following method has been used with very satisfactory results: First, thoroughly clean the surfaces affected; mix Portland cement with fresh water, without sand, to about the consistency of ordinary whitewash, and apply two coats with a whitewash brush. It will seldom be necessary to repeat the dose unless the boiler has been subjected to sudden changes of temperature, when it will be well to examine it carefully to see that the cement has not cracked. There have been many theories advanced as to the cause of this pitting action, among the more plausible of which are:

Galvanic action, caused by particles of copper or brass from the condenser tubes, air pumps and feed pipes, carried in with the feed water, which latter being acidulated, or more likely alkaline, becomes the exciting agent. However, inas-

much as these particles of copper or brass would by their weight gravitate to the bottom of the boiler, or lodge on the tops of tubes or furnaces, here is where we should expect to find the greatest corrosion or pitting, which, unfortunately for this theory, is not by any means the case. There is undoubtedly a very material wearing away of copper and brass pipes, due to the mechanical action of water and steam, aided possibly by any oily acid which may be present. This action is well shown at *B* in the plate; it is a part of an old main discharge pipe of a P. and O. steamer after six years' use.

Hydrochloric acid, produced within the boiler by the decomposition of the water, its hydrogen combining with the chlorides contained in the sea water, is by some regarded as the cause. If such were the case, the water would become strongly acidulated, and if it obtained sufficient strength to produce pitting, it would have a decided solvent action on zinc placed therein; moreover, numerous analyses made of water from boilers in which this pitting action has gone on seriously, have always shown it to give an alkaline reaction.

Decomposition of cylinder lubricants is assigned as another cause. The resulting fatty acids dissolve the brass of the condenser tubes, and passing into the boiler convert the water into a solution of copper, which acts electro-chemically on the water and iron, thereby causing corrosion or pitting. This action, however, would cause a wear on the condenser tubes proportional to that of the boiler iron; moreover, pitting is found to occur just as much when the condenser tubes are tinned. Again, as stated above, the water from marine boilers, except in very rare cases, is found to be distinctly alkaline; also, analyses of the water show not the slightest trace of copper in solution.

Presence of free oxygen is the basis of still another theory, it being thought that the presence of free oxygen in the boiler derived from the feed water would rapidly attack the iron. This theory may be partially true in so far as affects uniform corrosion, but that free oxygen could be *by itself* the cause of pitting seems extremely improbable.

Upon joining the last ship upon which I served, I found that

the vapor-escape pipe from the filter had been closed. The filter was a cast-iron box with closed top, having a connection with the air-pump discharge, and also fitted with connections to a weighted outboard valve. The feed pumps being above the filter, the latter was kept closed in order to create a pressure to force the water to the feed pumps. As a consequence much air was forced into the boiler along with the feed water, and much oil also kept it company. Now, although this boiler had been fed with oil and air in allopathic doses, a very careful personal inspection from above and below showed not the slightest trace of pitting or of undue corrosion.

Mr. J. B. Dodds recently read a paper before the N. E. Coast Institution of Engineers and Shipbuilders on "Corrosion and Pitting in Marine Boilers," in which he calls attention to the considerable percentage of "oily organic acid" present in combination with ferric, calcic and magnesic oxides in marine-boiler deposits, and this organic acid is derived from the mineral oil used as cylinder oil in the steam cylinders.

Mr. Dodds says: "The salts of the sea water, especially the magnesic chloride, cause the water to act chemically on the exposed metallic surface, and this action becomes greater at higher temperatures and densities of the water. This oxidation or chemical action at the same time produces electricity, as chemical action always does; the salts of the sea water becoming electrolysed or decomposed by the electricity, their bases combine with the 'oily organic acid' and produce the deposits found in the corroding boiler. As these bases combine and are neutralized by these 'oily organic acids' there is liberated an equivalent amount of the acid of the sea-water salt, which helps to still further increase the corrosion." This corrosion he considers the *cause* of electrical action, and not its *result*, as is generally considered, the sea water acting as the exciting liquid to produce chemical action and so electricity.

This theory of the acids of the sea-water salts being liberated or set free in the boiler in sufficient amount to produce pitting, or even undue corrosion, is open to the same objections as the hydrochloric acid theory. Mr. Dodds suggests that in place of

the zincs now fitted the water might be rendered non-exciting, or incapable of acting chemically on the iron or steel of the boiler, which would avoid the great difficulty in making and maintaining the metallic contact now necessary with zincs.

There are several ways of rendering the sea water non-exciting, and there are many compounds offered as meeting all the requirements, but some of these latter are liable to produce greater evils than those they seek to abate. It would certainly be a great advantage if some reduction could be made in the present costly application of zinc, and Mr. Dodds is of the opinion that a basic solution of zinc would effect this economy, and at the same time have the greater advantage that it could be introduced in small quantities at stated intervals, and diffusing itself throughout the boiler, all parts would be equally protected, and thus not only ordinary corrosion, but pitting also, due to the influences of rust or iron scale and variations of temperature, would be rendered innocuous.

Great care should be used in the selection of cylinder oils, and only those used having a vaporizing point at a higher temperature than that of steam at the pressure at which the boiler is worked.

In the discussion which followed on Mr. Dodds' paper, Mr. Walliker (Lloyd's inspector for boilers) made the statement that 25 per cent. of the steamers trading from the Tyne used no zinc, and that in his opinion its use in ocean-going steamers not subject to very bad water was in no degree necessary. The chief engineer of one of the largest fleet of steamers plying between England and Australia told him that they never used anything in their boilers but ordinary sea water, carrying the density at $\frac{3}{32}$, and he finds his boilers in excellent condition. Another plan which has been proposed for the protection of boilers is that of sending through them a feeble current of electricity. Insulated wires could be introduced at opposite ends of the boilers below the water-line; the current flowing through the water, a sufficient quantity of hydrogen would be set free to cover the iron surfaces of the boiler with a protective film, and so prevent scale deposits or corrosion taking place. One wire could be fastened

to the boiler shell and the other wire to a mass of zinc, preferably fitted in a suitable vessel outside the boiler constructed for the purpose of receiving it. The vessel should be attached to the boiler by a cock or valve, which should usually be open, but which could be closed at will so as to admit of examination and replenishing of the zinc at any time.

Of the large number of chemical substances introduced into boilers with the view to increasing the solubility of the contained salts by decomposing them, there is one which I think is largely recognized as beneficial and most effective. I allude to sodic carbonate, which acts well in preventing and removing incrustations consisting of both sulphate and carbonate of lime. These two salts, soda and lime, exchange their acids, the result being the formation of sulphate of soda, which is very soluble, and carbonate of lime, which, in the absence of any excess of carbonic acid, is insoluble and precipitates without forming a hard incrustation. The carbonate of lime after settling remains mostly as a sludge, which can be readily blown out when the boiler is under low steam. Before settling, however, this precipitate is carried by the agitation of the water to the surface, and remains for a time as a scum, when it may be easily disposed of by a judicious use of the surface blow.

Prof. Lewes, in "Service Chemistry," says: "If an alkali be added to the water in a boiler so as to absorb all carbonic acid, corrosion is stopped, and a piece of bright iron or steel may be kept perfectly uncorroded in such a solution." Again, "The solvent action of distilled water on metals rapidly attacks the plates in places where the presence of a trace of slag or other impurity renders the metal less dense or gives it a tendency to lamination. This can be avoided by using sodic carbonate and avoiding too frequent blowing off, the action of water on iron rapidly decreasing with an increase of density."

In the last two vessels on which I served sodic carbonate was used with most satisfactory results.

On one occasion, while along the Florida Keys, where the water contains an abnormal amount of lime, steam was on the main boiler for over two months continuously, and during this time all

the water used by the ship, steam launch, and a surveying party in a small schooner, was supplied from this boiler, in which upon being opened up at the end of ten weeks a scale was found on the crown sheets and back connection of about $\frac{1}{32}$-inch thick and easily detachable, coming off readily in large flakes from six inches to a foot square. It took two men about three hours to scale the boiler in good shape. Saturation was carried at about $3\frac{1}{2}$. Every day, when steaming, the surface blow was opened two or three times for a very short interval; mornings, just before spreading fires, the bottom blow was opened and about two inches of water blown off, or sufficient to maintain saturation. About two pounds of sodic carbonate dissolved in a bucket of water was introduced daily for a week or ten days, when the supply was cut down to about one-half this amount. The boiler never showed the slightest sign of pitting, and as near as I could judge the internal corrosion was practically *nil*.

In a coastwise steamer upon which I made several trips there were two three-furnace boilers in which the chief engineer took considerable pride, as well he might, as they were twelve years old, and all that had been done to them in that time in the way of repairs was the fitting of a new set of tubes and two or three small furnace patches. At that time these boilers were in a good state of repair. As much as twenty-five pounds of sodic carbonate was used every twenty-four hours, with most favorable results.

The real cause of pitting in boilers, although now largely checked, has never been satisfactorily explained. Undoubtedly this peculiarly destructive form of corrosion is due to no *single* cause, but rather to a *combination* of causes, which has yet to be discovered; it has been checked much as a doctor might check a disease of which he was unable to make a diagnosis, by administering all the different combinations of medicines he could think of as bearing on the case.

The following are some of the precautions used to prevent pitting:

Carefully pickling the boiler plates to remove all mill scale or oxide.

Fitting large quantities of zinc in the boiler.

Preventing the entrance of atmospheric air.

Using only the highest grades of mineral oil in the cylinders, and little of that.

Filtering the feed water to prevent the entrance of oil or other foreign substances.

Tinning the condenser tubes.

Using only pure water.

Changing the water in the boiler occasionally.

Use of sodic carbonate, and sometimes of other salts.

With this combination, in whole or part, pitting has been largely if not wholly checked.

Although the weight of opinion in regard to fitting boiler zincs is in favor of close metallic contact, yet experiments which have been tried go to show that zinc simply suspended in the water of the boiler gave equally efficient results. The analyses of many samples of boiler water have shown zinc in solution, and it is a question whether the prevention of corrosion is not principally due to zinc in solution rendering the water non-exciting, as described by Mr. Dodds.

The quantity and the disposition of the zincs fitted in a boiler depends somewhat upon various conditions, such as the age of the boiler, and whether it shows any tendency to undue corrosion; the kind and amount of service, and the kind of water used.

Rolled zinc, being purer, should always be used when possible in preference to cast zinc.

The Admiralty rule requires one slab 6 inches by 12 inches for every 100 square feet of tube-heating surface.

The boilers of the U. S. S. *Texas* are double-ended, 14 feet in diameter and 18 feet long, with 3,613 square feet of tube-heating surface; each boiler is fitted with 66 zincs 8 inches by 16 inches by $\frac{1}{2}$ inch. The length of time zincs will remain effective depends upon the amount of steaming and the condition of the boiler. A careful record of zinc consumption in boilers supplying engines of 1,000 I.H.P. (Indian trade) showed 10 pounds to 12 pounds of rolled zinc per 24 steaming hours when boilers were new; afterwards, when in good condition, free from undue corrosion, about 5 pounds per 24 hours of steaming.

Zincs to be effective should not be spaced over six feet apart, it having been ascertained by a series of experiments in England that they exerted their influence in checking pitting over only a radius of three feet. Zincs are of little or no use in the steam space, except when the boiler is out of use and kept full of water as a means of preservation, and in which case this portion of the boiler should contain from one-fifth to one-sixth the whole number.

Zincs deteriorate either by gradually wasting away or by a gradual change of substance, the latter being the much more common process. They become of a dark gray or black color, brittle and more or less friable, presenting a warped, cracked, or honeycombed appearance with apparently little of a metallic nature left in their composition. Even if placed in a crucible and heated to redness this resulting substance does not melt.

In filling the boilers, whenever the ship is in a basin or dock, they should always be supplied with fresh water, as the vegetable decay, mud, and sewerage usually present in such localities would act injuriously on the metal. If the ship enters a harbor where it is impossible to fill up with fresh water, and it is not advisable to fill from the sea, the only alternative is to retain the water already in use, although an occasional entire change should be made if we would preserve cleanliness and avoid danger from undue corrosion or pitting.

In raising steam in the ordinary Scotch boiler plenty of time should be taken, in order to prevent the severe strains resulting from expansion. Where no means are taken to start the circulation of the large amount of water under the furnaces, it is no uncommon occurrence, even though four or five hours are consumed, to have steam on the boiler while the bottom of the shell is still cold. In such a case the difference in length of the top and the bottom of the shell would amount to approximately a quarter of an inch in an eighteen-foot boiler, producing severe strains, and as a natural consequence, continual leakage along the bottom shell seams.

In illustration of the evil results of sudden changes in boiler temperatures the following fact is quite to the point. It was in

the winter season, and the vessel was at anchor off the Massachusetts coast one night, when at about 2 a. m., a flange gasket near the bottom of the boiler blew out. Fires were immediately hauled and the boiler blown down, a new gasket fitted, water run up, fires lighted and the ship ready to get under weigh at daylight. A few days later the vessel arrived in New York. Boilermaker's bill for caulking leaky joints and expanding tubes was about $75, and the mischief did not end here, as the tubes and seams soon leaked badly again, and were only checked after additional expense for fitting ferrules to tubes and cementing seams. It is perhaps superfluous to add that this event took place in the interim between the detachment of the engineer officer and the ordering of his relief.

Plate I shows the result of a test with a Scotch boiler in raising steam *with* and *without* a circulator, the conditions in the tests being as nearly alike as possible.

In vessels where there is no auxiliary boiler, and the boiler water-level is above the sea-level, it is a good plan to pump up to say a little over a half a glass, and two or three times before steam forms, to open the bottom blow and allow the water to fall an inch or two, thereby bringing the warmer water down to the bottom of the shell. Before the introduction of the hydrokineter it was a common practice to run a steam pipe into the bottom shell of the boiler and start in live steam from the auxiliary boiler shortly before lighting fires. Another and an excellent method of effecting circulation is by means of an auxiliary feed pump, having a branch suction to the bottom blow pipe, by which means the water is drawn from the bottom of the boiler and forced in near the water-level.

Boilers should always be fitted with internal feed pipes, preferably leading upward towards the water-level, thus not only giving the boiler a better circulation, but preventing the emptying of the boiler in case of accident to the feed valve; it also prevents corrosion of the boiler shell, which often occurs where no internal pipe is fitted, or if fitted, is so led as to project the feed water against the shell plate.

Dampers should be fitted in each uptake, so that when clean-

ing or banking fires the draft can be checked, avoiding the strong rush of air on the highly heated crowns and tube sheets. The writer can speak from solid experience in this matter, and can vouch for the usefulness of this appendage in avoiding leaks in furnaces, back connections, and tube sheets.

An inspirator or injector in each fire room is very useful, preventing the necessity of ever forcing cold water into the boilers; it should be provided with a swing check in delivery pipe, close to its entrance to the auxiliary feed pipe, or check valve, as the case may be. It is preferable for the injector to discharge into the auxiliary feed, for the reason that if it is desired to work the feed pump and injector at the same time, the pulsations in the feed pipe from the pump are apt to break the flow from the injector. If the latter is placed low in the ship it will sometimes refuse to work, especially with low steam, from its becoming flooded from the head of water; this can readily be obviated, however, by adjusting or partially closing the supply valve fitted in the suction pipe.

Before getting under weigh, it is a good plan to drain out any water which may have collected in the condenser, for even if it has not acted slightly on the brass or copper, it will generally contain more or less oil.

When under steam, variation or irregular working should be guarded against as much as possible; the water in the boilers should occasionally be tested for acidity, which can be readily done by means of a slip of litmus paper dipped in the salinometer. In cases where water losses are necessarily made up from the sea, blowing, except for the purpose of scumming, should not commence until a saturation of from 3 to $3\frac{1}{2}$ is reached, the surface blow being preferably used for this purpose when steaming, and the bottom blow when under low banked fires. When through steaming, no haste should be used in reducing the boiler pressure, but the steam should be allowed to work off gradually through bleeders or evaporators, the dampers should be nearly closed, only leaving enough opening to allow the escape of gas, and furnace doors open. After fires are hauled, care should be taken to wet them down only after

being removed from the boiler front. An excellent protection is afforded by a light plate of iron fitted in front of the ash-pits. The furnaces should finally be closed, and the boilers allowed to cool gradually. In case it is necessary to blow the boiler down instead of pumping it out when cold, the pressure should be allowed to drop to about 20 pounds, depending upon circumstances, thereby avoiding the severe jar liable with higher pressures. In case of jar it may frequently be checked by either opening or closing the blow valve slightly.

As soon as the boilers are empty they should be scaled, if necessary, thoroughly washed out with a steam hose, and then carefully drained and swabbed dry. Care should be taken to remove any loose scale, however thin, as it forms excellent little pockets or reservoirs for holding moisture; this frequently happens about the tubes and braces.

Heating surfaces of boilers using forced draft should receive extra care and attention as to their cleanliness.

It should be remembered that boilers aboard ships in commission deteriorate more rapidly when out of use than when under steam, and consequently this is the time they should receive the engineer's greatest attention. All steam or water connections should be kept carefully closed on the boilers out of use, to prevent the entrance of moisture from such sources. Water condensed in the escape pipe will sometimes find its way to the safety-valve seat, and when the valve is lifted, as it should be occasionally, it passes into the boiler. To prevent this, drain pipes should be fitted close to the valve below its seat.

After the furnaces, ash-pits, connections, and uptakes have been cleaned, and any necessary repairs have been made, the boiler should be closed, leaving off only the lower manhole; fires should be lighted in portable sheet-iron furnaces or trays and placed in the ash-pit of each furnace, the uptake damper being partially hauled so as to retain the heat. These fires should be lighted frequently, say three times a week, as long as the boiler is out of use. Each time after finishing with these trays place them with the smouldering coal in the lower manhole, and loosely secure the plate in position until they are needed again. The coke

will absorb much oxygen, and so tend to check internal corrosion.

Another method is to pump the boiler quite full of salt water, adding about 50 pounds of sodic carbonate per 100 cubic feet of space in the boiler, the right amount of carbonate being readily determined by placing a bright piece of iron in a sample of the boiler water. If the iron rusts after several hours of immersion, add more carbonate. Before closing the boiler the zincs should be in good condition, and additional ones fitted above the water line. Light fires should then be started to heat the water sufficiently to drive off the entrained air.

This method cannot well be applied to boilers of ships in commission, on account of the many disadvantages or difficulties which readily suggest themselves. Another method which has sometimes been adopted in boilers out of commission, and with very good results, is that of giving them inside and outside two or three coats of boiled linseed oil. The oil soon dries and furnishes a good protection. This *internal oil coating*, however, is liable to be the cause of violent lifting and priming of the water for a short time after the boiler is put in use again. Some years ago I made several trips on an excursion steamer, the boiler of which had been kept full of crude oil during the previous winter. The oil performed its duty well, the interior of the boiler being in excellent condition when opened up in the spring. Before use it was carefully washed out with a steam-hose; however, the first time the steamer got under weigh, the water rose slowly but surely to the top of the gauge-glass and remained there until the steamer reached its destination, which it did fortunately after only an hour's run, when the water fell in the same exasperating way until it was out of sight. It was about a week before this evil was entirely abated.

As stated above, all exposed portions of the boiler should receive a good coat of paint before they become thoroughly cold, or at any rate before they begin to show any signs of sweating; otherwise, as soon as steam is raised the paint will blister, crack, and peel off.

Never use whitewash on any portion of the boiler, as it greatly

promotes corrosion unless it is put on over a heavy coat of paint. At best it presents a slovenly appearance and requires constant renewal; moreover, as the paint should be renewed occasionally, it becomes necessary to thoroughly clean off the whitewash—a tedious, dirty job.

Boilers of ships spending much time in the tropics are comparatively short-lived, due to excessive corrosion from the warm, moist air, and when so stationed, extra exertions should be made to protect them as much as possible. Finally, at all times work the boilers as regularly, evenly, and as easily as the service permits.

The Thornycroft boilers of the torpedo boat *Cushing* have recently been removed for the purpose of overhauling and cleaning. After a year's continued hard service, including a severe test trial at the New York Navy Yard (see pp. 580, 581, Vol. II of the JOURNAL), they appear to be in very good condition. No leaks of any importance have developed, and the external corrosion is comparatively slight excepting as mentioned below. The internal surfaces of the drums show no pitting, and only very slight corrosion, being covered with a thin coating of a light powder, probably largely composed of calcic carbonate. There was no means of determining the internal condition of the tubes. About 100 pounds of zinc have been kept in each of the three drums.

Assistant Engineer B. C. Bryan, U. S. Navy, who is in charge of the *Cushing's* machinery, writes as follows:

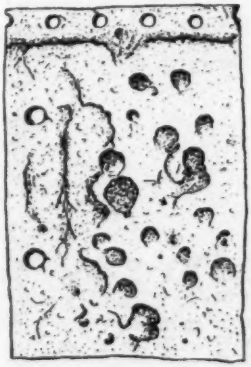
"As to the external corrosion, it is greatest at the fire room ends (fronts) and on bottoms of both lower drums of both boilers, and on the outer two rows of tubes of after boiler. The tubes of the forward boiler seem to be totally free from this corrosion, and, notwithstanding the fact that it was this boiler which underwent so severe a trial at the New York Navy Yard, it seems totally unharmed, and the tops of the lower drums and the tubes still have the bright glossy-blue appearance which a plate takes after leaving the rolls, showing no corrosion or leaks anywhere. It is a remarkable fact, and one that I cannot altogether account for, that the moisture seems to collect and hang in small

drops at the bend of the outer row of tubes of the after boiler, where they bend just before entering the lower drums, and this moisture has facilitated corrosion, so that these tubes have become slightly rough. This action does not seem to occur at all in the forward boiler.

"It was supposed that the galley helped to heat the forward boiler (it being in the next compartment, and at times keeping the bulkhead quite hot), but the same phenomenon occurs in the foundry, where the boilers are now stored; these tubes in the after boiler are always wet when the weather is moist or foggy, while in the forward boiler they are either only damp or perfectly dry. The zinc disintegrates very rapidly in these boilers, and has to be removed after a very few trips at full speed. It will last, perhaps, about five or six weeks, steaming three to four hours a day at full steam pressure (250 lbs. per square inch), but its lifetime seems to depend upon the pressure carried, the brand of zinc used, and the accuracy or quality of its connection with the boiler. The disintegration is very peculiar, and I believe it to be due to the forcing of solid matter into the pores of the zinc by the high pressure, and softening of the zinc at the high temperature (about 407° F., zinc melting at 680° F.) This type of boiler, like all tubulous boilers I have ever seen, needs constant examination and care, and it should either be put into a ship so as to be readily accessible at all times, or should be lifted out and thoroughly cleaned and painted externally at least once every six months when in use."

— A —

— B —



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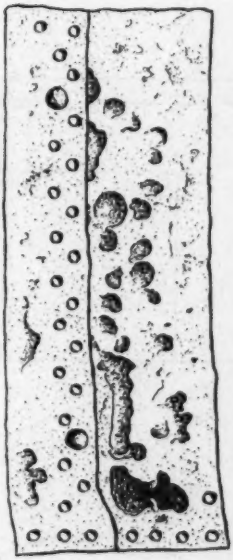

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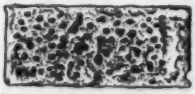


— E —

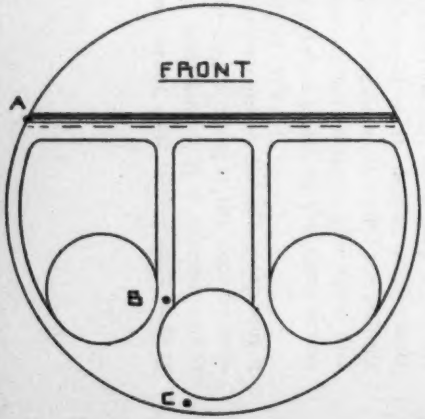
EXPERIMENTS IN RAISING STEAM FROM TIME OF LIGHTING FIRES

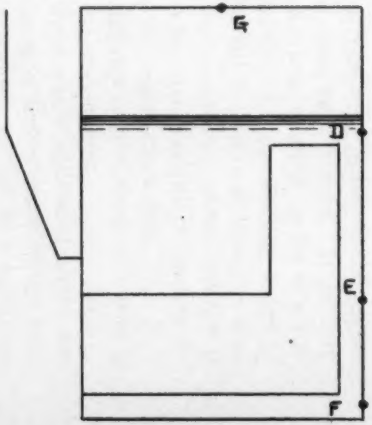
WITH CIRCULATOR

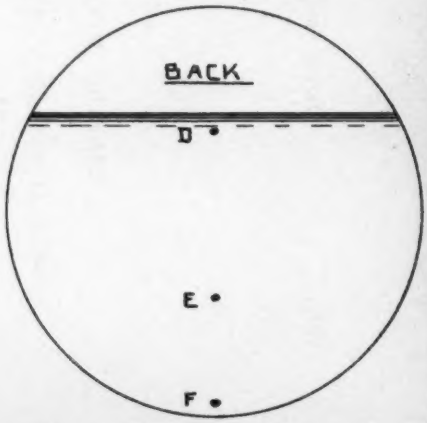
TIME	TEMPERATURES A	B	C	D	E	F	G
12.30 P.M.	59	60	60	60	60	60	60
1.	92	90	80	88	88	86	72
1.30	154	152	140	146	146	144	114
2.	192	190	180	180	178	178	166
2.30	218	212	201	207	206	206	216
3.	246	240	229	236	230	230	250

WITHOUT CIRCULATOR

TIME	TEMPERATURES A	B	C	D	E	F	G
10.0 A.M.	58	60	60	66	68	68	80
10.30	86	84	64	78	76	68	80
11.	148	144	64	132	128	68	110
11.35	212	210	68	192	194	64	200
12.05	250	245	88	241	230	66	250







REAR

FRONT

XI.

ENGINE ROOM SIGNALS.

By Assistant Engineer H. P. Norton, U. S. Navy.

The bell signals so long used in the naval service were never a very satisfactory method of transmitting orders to the engine room, particularly for vessels with twin screws. It is very natural, therefore, that they have been omitted on the new vessels, and mechanical telegraphs fitted for transmitting orders to the engine rooms; and as with this appliance at least one accident has happened from a misunderstanding of the order, it is evident that there is still room for improvement, at least in the arrangement of the signals on the engine room dials.

The following are some of the improved methods of transmitting orders from the deck to the engine room:

One of the first methods used was a system of shafts and bevel gears. There was a pedestal on deck or on the bridge fitted with a horizontal dial and a pointer moving in a horizontal plane. The signals, stop, stand by, and the several rates of speed ahead and astern were engraved on the horizontal dial; in the engine room there was a vertical dial fitted with a pointer, and the same signals were engraved on its face as on the dials on deck. By moving the lever at the deck dials until the pointer indicates the desired order, the pointer on the engine room dial is moved, by the shafting and bevel gears, to the same order, and at the same instant a gong is struck.

This system is a great improvement on the old gong, but it does not have a reply from the engine room to the deck to indicate that the order has been understood; it is expensive to fit and to keep in good working order, as it is necessary to keep

the shafts in line so that the lever may be moved with as little power as possible.

The faults in this system are at least partially remedied by the reply engine room telegraph. There are several of these in use, but the general features are the same in each, and I will describe Homsey's mechanical telegraph, see figures 1, 2, 3, 4, 5, 6 and 7, plate 1. The bevel gears and shafts are replaced by wires, chains, and fair leaders or guide pulleys. There are two wires for the signals from deck to the engine room, and two for the signal from the engine room to the deck. At each dial the hand lever has a pointer attached to it, which moves with the lever as shown in figures 1 and 3. This pointer moves around the outer edge of the dial. The other pointer is not connected with the lever, and its outer end moves around the inner edge of the dial, so that both pointers may indicate the same order. The inner pointer is connected to a drum, shown at *C*, figure 6, and the wires and chains already mentioned are secured to this drum, so that as one portion of the chain is wound on the drum an equal portion is unwound.

The drum *D*, figure 6, is secured to the lever and moves with it, and is fitted with chains the same as the drum *C*.

The wires and chains that are connected to the wheel *C* at the deck dial are connected to the wheel *D* in the engine room dial, so that in each case the movement of the lever and pointer at either dial causes a corresponding movement of the inner pointer at the other dial. The deck dial has a catch on the lever so that it may be secured in any position (see figure 2), and the engine room dial is fitted with a gong which is struck each time the inner pointer moves to an order. The striking gear is shown in figures 5, 6 and 7; the hammer *A*, figure 5, being loose on the stem so that the spring throws it against the gong.

The wires are fitted with turn-buckles so that they may be kept tight and the pointers adjusted.

When it is desired to transmit an order from the deck to the engine room, the lever at the deck dial is moved until its pointer is opposite the desired order, the motion of the lever moves one of the drums, and by the wires already mentioned the inner

pointer at the engine room dial moves through the same arc and indicates the same order as the outer pointer of the deck dial. As soon as the order is understood in the engine room, the lever at the engine room dial is moved until the outer pointer is opposite the inner one, and this causes the inner pointer on the deck dial to move until it is opposite the outer one and indicates at once that the order has been understood.

Another form of mechanical telegraph used to some extent is that of Chadburn & Sons. Its general appearance and details are the same as of the one already described, the only difference being the use of two gongs at the engine room dial and three pointers at the deck dial. The additional pointer at the deck dial is moved, automatically, by the reversing engine or the links, so that it points to either *ahead* or *astern*, and is in this way an automatic check and shows that the orders have been executed.

The two gongs at the engine room dial are for indicating *ahead* and *astern* signals; a deep-sounding gong being struck for signals to go *ahead* and a shrill gong for signals to go *astern*.

Although the mechanical reply telegraph has been used to only a very limited extent in United States naval or merchant vessels, it is almost universally used on all foreign naval and merchant vessels, and its only failures have been due to neglect and indifference on the part of the persons responsible for its being in proper order, or, as in the case on board one of the new vessels, the order was not understood on account of the dial being improperly engraved. If properly fitted, the best forms of mechanical reply telegraphs leave very little to be desired and very little room for improvement, the great objection being that the wires must be led as direct as possible from the deck to the engine room dial; this may be expensive, especially when watertight bulkheads have to be passed, and in naval vessels they are liable to be shot away.

Any number of deck dials and transmitters may be connected to the same dial in the engine room. The same form of telegraph with a different dial may be used to signal the number of revolutions from the deck to the engine room, and it may be

used to advantage to signal from the engine room to the fire rooms.

To obviate the objections in regard to the lead of the wires in mechanical forms of telegraph, several forms of electric engine room telegraphs have been invented, the most successful of which is the electric reply telegraph invented by J. B. Willis and manufactured by Elliott Bros., London, England. The external appearance of the dials, levers and pointers, except the engraving, is the same as for the mechanical reply telegraph, and the details are shown in figures 1, 2, 3 and 4, plate 2.

The order *stand by* is omitted from the dials, as the inventor does not consider it necessary, as the signal gong rings as soon as the circuit is made preparatory to giving a signal.

The connecting cables may be in duplicate or triplicate, each being led through a different part of the vessel, and it has been proposed to lead them through the double bottom.

While the cost of fitting the electric telegraph in a vessel may be less than for a mechanical one, its first cost is much greater; it is more expensive to keep in order and requires much more attention, and, as will be seen from an inspection of the drawings, the mechanism in each transmitter is very complicated when compared with that of the mechanical reply telegraph already described. In spite of this complication of parts, the committee ordered by the English Admiralty, in 1887, to report on the various systems of signalling on board ship, reported very favorably on the Willis system, and in February, 1889, the system had been found so successful on the *Impérieuse* that it was fitted on the *Camperdown*, *Rodney* and *Aurora*, and was to be fitted on the *Magicienne*, *Marathon*, *Galatea*, *Medusa*, *Medea*, and probably on the yacht *Victoria and Albert*.

As already stated, the external appearance of the electric and mechanical reply telegraphs is the same, and the method of transmitting an order and its reply is the same in each case.

The following is a description of Willis' electric telegraph:

Figures 3 and 4, plate 2, show a front and sectional elevation. A is a central pin which works in a bearing R and is connected to the lever A^1 at the back of the case. This lever is carried by

the handle B^1 which also has the arm B^3 which carries the outer pointer on the dial. The lever A^1 has its fulcrum at B^4 and has a locking bolt B^2. When the handle B^1 is grasped and the lever A^1 pulled towards it, the locking bolt is withdrawn and the central pin A is pushed forward, the point Q coming in contact with a spring (not shown) supported from the case of the instrument; this completes the electric circuit and rings the signal gong as already mentioned. The handle B^1 and pointer is moved to any desired order, and when the lever A^1 is released, the locking bolt springs back into place and the circuit is broken.

The handle B^1 is connected to the bearing R, and secured to the bearing R is the plate X. This plate carries a spring box C working on a center C^1. Around the spring box C there is a chain D which passes over rollers F^1 secured to the top of the arms G. The arms G are pivoted on the plate X and are connected at their bottoms by the spiral spring G^1.

The chain D, after coiling around the spring box C and passing over the rollers F, is secured to the pivot S, figure 4, which is secured to the plate Y, and through this to the contact-making arm N. On the circumference of the plate X there is a small notch, into which fits a roller, M, which moves with the contact-making arm N; the roller M is held in the notch by the tension of the spiral spring T.

The contact-making arm N, through the gear wheel Y^1, which has the same center as the plate YY, is geared to a train of wheels enclosed between the plates KK, and this train is connected to the regulating fly J. On any movement of the contact maker N taking place, the train and fly are set in motion.

A locking arm, L, is secured to the plate Y by the pivot S. The end of the pin A is made in the form of a key, and a corresponding hole is made in the arm L, so that when the handle B^1 and lever A^1 are gripped, and contact made and the pin moved, it is impossible for the contact to be again broken until the positions of the key and hole again coincide. 1, 2, and 3 are a series of contacts insulated from each other. Their number is the same as the indications required, and the contact arm

makes connection with each as it passes. *O* are buffer spring stops against which the stop arm *P*, figure 2, brings up when the arm B^1 is moved to its farthest position on each side of the vertical position.

When the handle B^1 is moved slowly in either direction, the contact maker *N* and its fixed connections move with the plate *X*, as the tension of the spring *T* holds the roller *M* in the notch in the plate *X;* but if the handle B^1 is moved quickly this tension is overcome, and the plate *X* moving with the handle B^1 moves the notch away from the roller *M;* that arm *G*, in the direction towards which the contact maker *N* has to travel, is moved inwards and the chain *D* would become slack, but that the other arm *G*, by means of the spring G^1, is moved in an outward direction and the slack of the chain *D* is taken up by the spring box *C*. The spring box *C* has a tendency to always bring the contact maker *N* to the same position as that occupied by the handle B^1, the motion of the contact maker being retarded and regulated as required by the train of wheels and fly *J*. This prevents the contact maker from being moved too fast for the proper action of the receiver.

When the roller *M* is brought back to its position in the notch, the locking bolt is in position, and the key on pin *A* coincides with the hole in the locking arm *L*, the circuit is broken.

The contact ring 1, 2, 3, is insulated from the case on ebonite, and no matter how many indications are required on the dial, every third contact block is connected as shown in figure 3. All the No. 1 blocks are connected together, all the No. 2 blocks and all the No. 3 blocks.

Four wires are brought into the case, three being connected to the No. 1, 2 and 3 blocks respectively, the fourth being connected to the spring (not shown) against which the contact point *Q* of the pin *A* is pressed when the handle B^1 and lever A^1 are gripped, and this connects the fourth wire with the blocks 1, 2, 3 alternately as the contact maker *N* travels over the blocks. Figures 1 and 2, plate 2, show the receiver; *a*, *a*, *a*, are three electro-magnets; *B*, *B*, *B*, are their armatures which are pivoted

at B^1; c, c, c, are ball bearings, and d, d, d, are connecting rods connecting the armatures to the pin on the axis. S is an adjustable spring whose tension is sufficient to keep the armatures and connecting rods in a state of equilibrium, so that no matter which armature is attracted, it will remain in that position until the current is broken, notwithstanding any jarring or concussion the instrument may receive. Figure 2 shows a plan of the axis E and gear wheels; the axis E terminates in a worm E^2 which gears into a worm wheel F; G is a bevel wheel secured to the same axis as worm wheel F, and this gears into a bevel pinion G^1, which is secured on the axis H, to the end of which the inner pointer on the dial is secured.

By varying the proportion of the teeth of the wheel and pinion the pointer may be made to move any required distance over the face of the dial according to the number of indications required. Although not shown in the drawing, the end of axis E, beyond the worm, has three small holes or notches at equal distances from each other, and a light spring forces a conical point into one of these notches when the armatures are attracted. This serves to steady the pointer. The bevel wheel G has two pins on its upper surface which serve as stops when the pointer has reached its maximum travel on either side.

The action of the receiver is as follows: When 1 and 4 terminals are joined, the armature of No. 1 is attracted, and the connecting rod and pin on axis E are moved so that they are in one straight line at right angles to the armature; the current being broken, everything remains in the same position. If any of the other terminals are connected, the same motion takes place; that is, no matter which armature is attracted, the connecting rod and pin E always assume such a position that they are in the same straight line at right angles to the armature.

Switches are fitted, one for each instrument, for cutting out any instruments not in use.

The bells used are the ordinary electric trembling bells, and they can be joined in multiple arc or by a special relay. The latter is the better arrangement, as it prevents all chance of leaving the instrument contacts in circuit and the consequent running

down of the batteries without attention being called to it by the ringing of the bells.

Mr. Willis has patented a revolution telegraph, in which the mechanism is the same as in the one just described; but instead of the usual signals being engraved on the dial, it has numbers which indicate the number of revolutions to be made.

As will be readily seen from an inspection of the drawings, the electric reply telegraph is very much more complicated than the mechanical one. It is not so certain in its action, and it is absolutely necessary to keep it dry. Its first cost is greater, and it costs more for maintenance than the mechanical one; but as it has been adopted in the English navy, and a plant fitted in the Portsmouth dockyard for the instruction of officers, it must be satisfactory in service.

LeClanché cells are used, and, as already stated, when the locking bolt is in position, the circuit is broken, so that there is no loss from the batteries. The bell rings as soon as the circuit is made, so that it is not necessary to have the order "stand by."

The mechanical and electric reply telegraphs are very satisfactory in service, and when in proper condition, there does not seem to be much choice between them; but the mechanical system has a great advantage over the electric system as regards simplicity, is absolutely positive in its action, and can be kept in order by very little attention; in fact, with ordinary attention, there is no excuse for its ever failing. I do not consider that there is any room for comparison between the old bell signals and the mechanical or electric telegraphs, as with the telegraph the last order is always indicated on the dial, while with bells it is a thing of the past as soon as the signal is made, so that if there are any doubts in regard to what was intended by the officer on deck, there is no means of deciding without a great deal of delay. On one of our vessels, where both kinds of signals were fitted and used, the bell signal was the only one that ever failed, and I think now it is only used to give boat signals.

I would suggest the following changes in the dials, which can be used with either form of telegraph:

1st. All dials must be identical in every respect, so that when

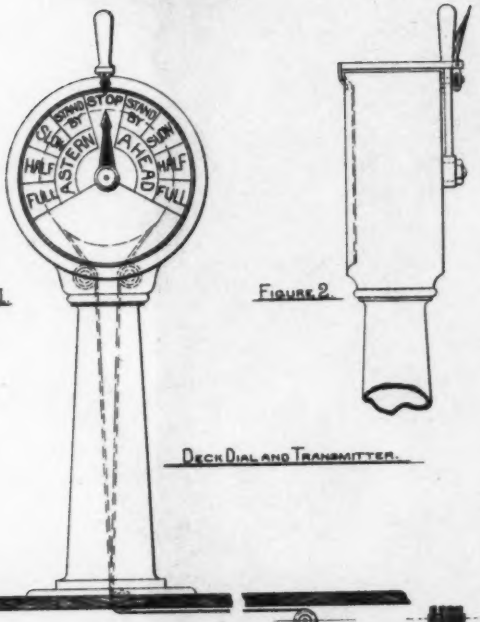


FIGURE 1.

FIGURE 2.

DECK DIAL AND TRANSMITTER.

FIGURE

FIGURE 3.

ENGINE ROOM DIAL AND TRANSMITTER.

PLATE I.

FIGURE 5.

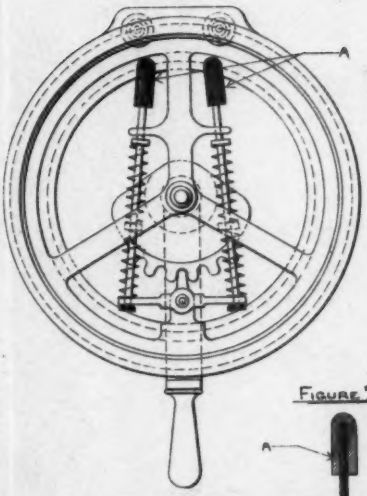


FIGURE 6.

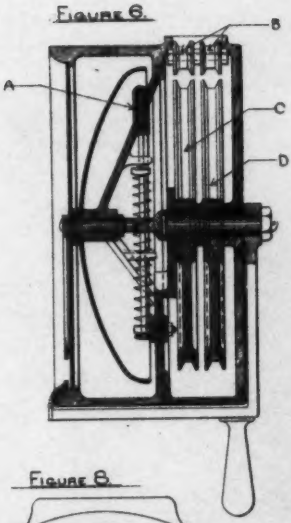


FIGURE 7.

FIGURE 8.

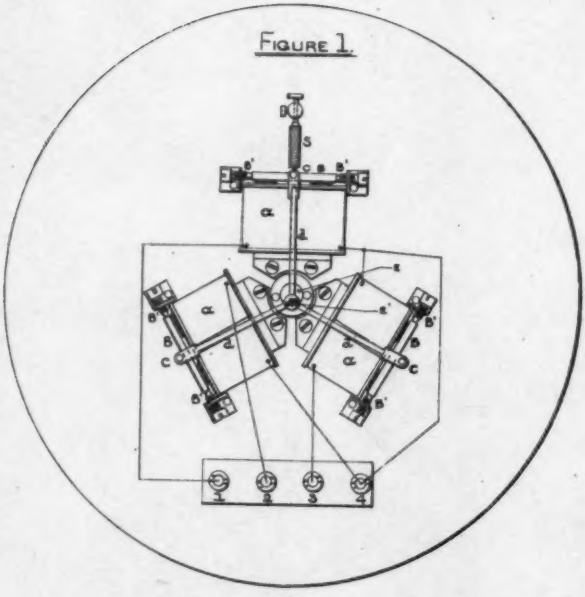
FIGURE 4.

MECHANICAL TELEGRAPH
TO
ENGINE ROOMS.

N°

ANSMITTER.

FIGURE 1.



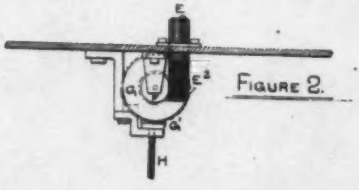


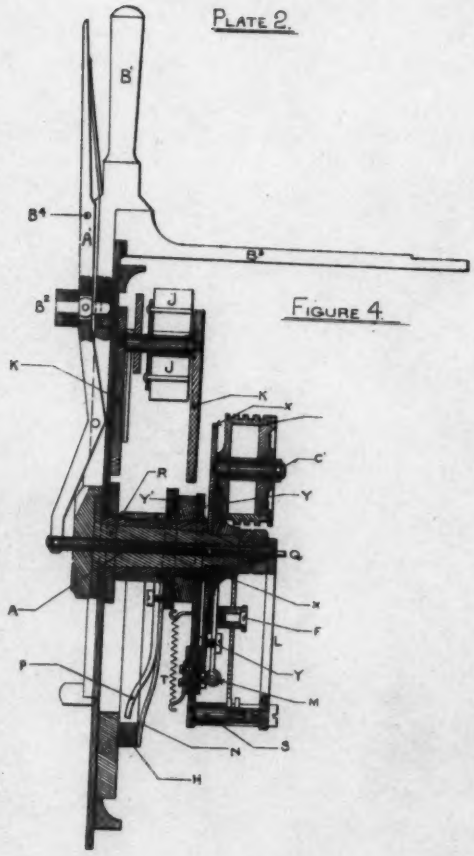
FIGURE 2.

ELECTRIC TELEGRAPH TO ENGINE ROOMS.

PLATE 2.

FIGURE 3.

FIGURE 4.



facing the dial, regardless of its position on board ship or in the engine room, the same relative position of the pointers will indicate the same order.

2d. The pointers should be vertical when indicating STOP, and motion from STOP *with* the hands of a watch should indicate AHEAD, and *against* the hands should indicate BACK.

3d. The dials should be plainly marked, so that the orders may be readily seen; the words *ahead* and *back* being used instead of *ahead* and *astern*. The words *ahead* and *back* should be engraved on differently colored enamel backgrounds, red for *back*, and white for *ahead*, all engraving being cut deep and filled with black enamel.

4th. There should be an order *stand by* for *ahead* and one for *back*, and the rates of speed in each direction should be indicated by numbers.

Figure 8, plate 1, shows a dial such as is proposed in the above suggestions.

XII.

CONTRACTORS' FULL POWER FORCED DRAFT TRIAL OF THE U. S. S. *BENNINGTON.*

By Assistant Engineer Albert Moritz, U. S. Navy.

A four-hour full-power forced-draft trial of the *Bennington's* machinery was made by the contractors, N. F. Palmer, Jr., & Co., Quintard Iron Works, New York, on Long Island Sound, on Thursday, April 2, 1891, with the following engineers of the U. S. Navy on board to report the performance: Chief Engineers A. W. Morley, W. W. Heaton and E. A. Magee; Passed Assistant Engineers H. N. Stevenson, F. H. Eldridge and Howard Gage; Assistant Engineers C. A. Carr, F. M. Bennett, W. Strother Smith, DeW. C. Redgrave, M. A. Anderson, Albert Moritz, H. G. Leopold, C. W. Dyson and W. C. Herbert.

The *Bennington* is a twin-screw steel gunboat of the same general dimensions, rig, and armament as the *Concord*, from which she differs only in a few details. The principal dimensions and data of the *Concord* are given in the first number of the present volume of this Journal, and the same will answer for the *Bennington.*

The receivers were enlarged by additional 4½-inch exhaust pipes on the high and intermediate pressure cylinders. Additions were also made to the Marshall valve gear of the same cylinders, to equalize the movement of the valves, and at the same time to add steadiness. See accompanying plate.

Performance.—The *Bennington* left her wharf at the foot of

East 13th Street, New York, N. Y., at 12.57 P. M., March 31, 1891, and proceeded under natural draft to Long Island Sound, where a short preliminary trial under moderate forced draft was made. The ship anchored off City Island for the night, and the following morning, April 1, began a full-power trial at 9 A. M., which was unexpectedly stopped at 10.20 A. M., by the breaking of the piston rod of the circulating pump of the port engine. The rod was of 2-inch steel, turned down to $1\frac{1}{4}$ inches to receive a brass covering $\frac{3}{8}$ inch thick. The break was square across at the crosshead end of the brass covering. The fracture showed highly crystalline and only a small portion appeared sound.

The trial was declared off at 10.20 A. M., and the ship returned to an anchorage off City Island, under the starboard engine, the port engine being run at moderate speed by using the water service pump on the main condenser.

While at anchor both the starboard and port circulating pumps were refitted with rods of Tobin bronze.

The following morning, April 2, a very successful trial was made. It began at 10 A. M., and was finished at 2.30 P. M.; the results were computed from 10.30 A. M. to 2.30 P. M.

The coal used was anthracite, egg size, of excellent quality, hand picked, furnished from the Pardee, Old Hazelton mine, No. 6 hole; it burned freely, made no clinker, and contained but nine per cent refuse.

The coal was bagged and carefully weighed. The ashes were weighed perfectly dry.

The engines, boilers and auxiliaries worked very satisfactorily. The lock nut securing the piston rod of the starboard circulating pump worked loose and required constant attention during the trial.

There was no heating of any of the journals except the crank pin of the port low-pressure cylinder, upon which a small stream of water was kept running for a few minutes.

Indicator cards were taken from each end of the main cylinders at intervals of fifteen minutes, and from the air and circulating pumps every hour.

The blowers were run constantly during the trial and were

indicated. In addition to other duties, Assistant Engineer F. M. Bennett succeeded in getting two excellent cards. The one shown on plate was taken when the blowers were making 591 revolutions.

A feed pump was indicated after the trial, when working under the average conditions of the trial.

The run was made in a smooth sea, against a fresh easterly breeze and against tide. The average speed during the four hours, as observed by Pilot F. W. Bell, was 16 knots. Considering the strong easterly wind that had been blowing for two days previous to the trial, the average current was not less than $1\frac{1}{2}$ knots. With this allowance the average speed of the ship was 17.5 knots.

The maximum speed was made between Matinicock Point and Eaton's Neck, a distance of $11\frac{1}{2}$ knots in 41 minutes. Allowing 1 knot for current, this gives a rate of 17.8 knots.

It is worthy of remark that during the trial the limits of variation were very close. The steam pressure in the boilers varied from 162.3 to 169 pounds; at engines from 158 to 165 pounds; revolutions, starboard, from 149.2 to 152; port, 149 to 152.6; horse-power, starboard, from 1,586.59 to 1,698.95; port, 1,633.27 to 1,718.97.

It is also worthy of observation to note the small percentage of horse-power developed in auxiliaries as compared with the horse-power developed in main engines. With the exception of the *Concord*, the horse-power developed in the air and circulating pumps in comparison with that developed in the main engines is less than on any other recorded trial. This speaks well for the design of the pumps, which were built by M. T. Davidson, of Brooklyn. An accompanying plate shows the design and plan.

Tabor indicators, previously tested and carefully selected, were used on the main engines and Crosby's on the auxiliaries.

The plates and tables following show how and to what extent corrections were applied.

There was an average reduction of 4.29 per cent. on the uncorrected mean pressures of all the cylinders.

The following table was compiled by Passed Assistant Engineer F. H. Eldridge from observations in the after fire-room:

COMPARATIVE TABLE OF FIRING IN AFTER FIRE ROOM.

Date of Trial.			Feb. 26.	Feb. 28.	April 1.	April 2.
Period under observation			2 hr. 8 m.	4 hr.	1 hr. 15 m.	4 hr. 30 m.
Number of times furnaces were coaled			22	56	17	65
Number of times furnaces were coaled per hr.			10.31	14	13.59	14.44
Average interval between coalings in mins			5.4	4.3	4.4	4.2
Ditto for one furnace			32.2	25.7	26.5	25
*Time door was open at coaling in secs			68.3 average of 7 observations.	1 man 48.2 1 man 72.3 1 man 54.3	1 man 62.4 1 man 67.8	1 man 58 1 man 61.3
Ditto average for all coalings			68.3	56	65.1	59.6
	Boiler.	No. Furnace.				
Number of times each furnace was coaled	C	1	3	10	3	11
		2	3	9	2	11
		3	4	8	3	10
	D	1	4	11	3	11
		2	5	9	3	11
		3	3	9	3	11
Number of times per hour each furnace was coaled	C	1	1.62	2.5	2.4	2.44
		2	1.62	2.25	1.59	2.44
		3	1.88	2	2.4	2.22
	D	1	1.88	2.75	2.4	2.44
		2	2.34	2.25	2.4	2.44
		3	1.62	2.25	2.4	2.44

*On February 26 only 7 observations of times doors were open were taken, and these at random. On February 28 the fireman on boiler D was changed at the end of 1 hour and 40 minutes; 48.2 seconds was the time for fireman on boiler C; 72.3 seconds for fireman on boiler D, and 54.3 seconds for the relief fireman. The times for April 1 and 2 are for boilers C and D respectively.

The turning and other trials had taken place on the afternoon of February 28, 1891, the date of a former trial, and had resulted as follows:

	Time to put helm over.	Helm angle.	Revolutions. S.	Revolutions. P.	Time to complete circle.
Hard astarboard, both screws ahead	20 sec.	37°	121	111	4 m. 35 sec.
Hard aport, both screws ahead	17 sec.	37°	112	110	5 m. 45 sec.
Hard astarboard, S. screw ahead, P. screw stopped	18 sec.	37°	110	—	5 m. 30 sec.
Hard aport, P. screw ahead, S. screw stopped	14 sec.	37°	—	102	5 m. 20 sec.
Hard astarboard, S. ahead full speed, P. astern half speed	18 sec.	37°	120	70	6 m. 15 sec.
Hard aport, P. ahead half speed, S. astern full speed	18 sec.	37°	106	78	8 m. 33 sec.

The heel of the ship in turning was small, and the circles made were of moderate size. A strong wind was blowing at the time.

From full speed ahead to full speed astern, by signal, head-

way stopped in 1 minute 5 seconds, advance (estimated) 125 yards.

At nearly full speed the helm was put over by hand 23½° with four men at the wheel. The change from steam to hand steering was made in 1 minute 5 seconds.

The following tables show the points of valve-setting for the trial:

U. S. S. *BENNINGTON.*

STARBOARD ENGINE—STEAM VALVE SETTING.

IN AHEAD GEAR.

1. POSITION OF CUT-OFF BLOCK ONE INCH FROM BOTTOM OF SLOT.

	H.P. Cylinder.		I.P. Cylinder.		L.P. Cylinder.	
	Crank End.	Cover End.	Crank End.	Cover End.	Crank End.	Cover End.
Lead	3/16	3/16	7/16	7/16	3/16	3/16
Maximum Valve Opening	1 3/16	2 1/16	2 3/16	1 13/16	1 3/16	1 3/16
Steam Follows	19 1/2	23	23 1/2	21 1/2	19 1/2	22 3/16
Maximum Exhaust Opening	3 1/16	3 1/16	3 1/16	3 1/16	3 1/16	2 13/16
Release	26 1/2	27	27	26 1/4	26 1/2	27 1/16
Compression	26 1/2	27	25 3/16	25	24 1/2	26 3/16
Exhaust Lead	2 1/16	1 7/16	2 1/16	2 1/16	1 3/16	2 3/16
Lap { Steam Side	1 3/16	1 3/16	1 3/16	1 3/16	1 3/16	1 3/16
Lap { Exhaust Side	0	0	1/16	0	1/16	0
Travel	7		7 1/16		6 2495	
Position of Eccentrics ahead of Center Line through the Cylinders	5° 45′		7° 15′		7° 15′	

2. WITH CUT-OFF BLOCK ONE AND ONE-HALF INS. FROM BOTTOM OF SLOT.

Lead	7/16	1/16	...	...	...	...
Maximum Valve Opening	1 7/16	1 1/16	...	...	...	...
Steam Follows	18 1/2	21	...	...	...	...
Maximum Exhaust Opening	3 1/16	3	...	...	...	...
Release	26 1/2	26	...	...	...	...
Compression	26 1/2	26 1/2	...	...	...	...
Exhaust Lead	2 1/16	1 1/16	...	...	...	...
Lap { Steam Side	1 3/16	1 3/16	...	...	...	...
Lap { Exhaust Side	0	0	...	...	...	...
Travel	6 1/16					

U. S. S. *BENNINGTON.*

PORT ENGINE—STEAM VALVE SETTING.

IN AHEAD GEAR.

1. POSITION OF CUT-OFF BLOCK ONE INCH FROM BOTTOM OF SLOT.

	H.P. Cylinder.		I.P. Cylinder.		L.P. Cylinder.	
	Crank End.	Cover End.	Crank End.	Cover End.	Crank End.	Cover End.
Lead	3/16	1/8	3/16	3/16	1/4	3/16
Maximum Valve Opening	1 3/16	2	2 1/16	1 3/16	1 1/4	1 1/16
Steam Follows	19 1/2	22	21 1/2	21 1/2	20	22
Maximum Exhaust Opening	3 1/16	3 1/8	3 1/16	2 13/16	3 1/8	2 7/16
Release	26 1/2	26 1/2	26 1/2	27 1/8	27 1/8	27 1/8
Compression	26 1/2	26 1/2	25 1/2	26 1/8	25 1/2	26
Exhaust Lead	2 1/8	1 1/8	2 1/2	1 1/8	1 1/8	1 1/8
Lap { Steam Side	1 1/8	1 1/8	1 1/8	1 1/8	1 1/16	1 1/16
Lap { Exhaust Side	0	0	1/8	0	1/8	0
Travel	7 1/16		7.224		5 11/16	
Position of Eccentrics ahead of Center Line through the Cylinders	5° 45′		7° 15′		7° 15′	

2. WITH CUT-OFF BLOCK ONE AND ONE-HALF INS. FROM BOTTOM OF SLOT.

Lead	1/4	1/4	...	...	...	...
Maximum Valve Opening	1 1/2	1 1/2	...	...	...	...
Steam Follows	18 3/4	21 1/4	...	...	...	...
Maximum Exhaust Opening	3 1/16	3 1/8	...	...	...	...
Release	26 1/2	26 1/2	...	...	...	...
Compression	26 1/2	26 1/2	...	...	...	...
Exhaust Lead	2 1/8	1 1/8	...	...	...	...
Lap { Steam Side	1 1/8	1 1/8	...	...	...	...
Lap { Exhaust Side	0	0	...	...	...	...
Travel	6 1/16					

The trial crew, under Chief Engineer R. W. Peck, was composed of two assistant engineers, five oilers, two water tenders, eight firemen, nine coal passers (five of whom were engaged in handling bagged coal), and one lamp trimmer.

At the close of the official trial the ship was headed for New London, Conn., and came to anchor off that port at 3.16 P. M.

The following day, April 3, at 5.54 A. M., the anchor was weighed and the ship headed for New York, with fires under two boilers and natural draft. At 7.15 A. M. the blowers were started. Arrived off New York at 3.22 P. M., and secured to pier at East Thirteenth Street at 4.15 P. M.

Since the trial the boilers, main cylinders and valves, journals

of main engines, and feed, air and circulating pumps have been examined and found to be in excellent condition.

WEIGHTS.

Propelling machinery	278.73 tons.
Water in above machinery (6 inches above highest heating surface in boilers)	62.37 tons.
Tools, instruments and duplicate pieces	9.40 tons.
Miscellaneous machinery	3.92 tons.
Total weight	354.42 tons.
One main boiler without fittings, empty	23.51 tons.
Water in one boiler (6 inches above highest heating surface)	14.98 tons.
All boilers, fittings, water, uptake, smokepipe, and all machinery in fire rooms	215.33 tons.

DATA OF TRIAL.

			Starboard.	*Port.*
Pitch of screw propellers (three-bladed)			13′8½″	13′8¼″
Draught at beginning	Forward 13′ 0″ / Aft 15′ 2″	Mean	14′ 1″	
Draught at end	Forward 12′10″ / Aft 15′ 0″	Mean	13′11″	
Draught, mean, for trial	Forward 12′11″ / Aft 15′ 1″	Mean	14′ 0″	

SYNOPSIS OF STEAM TRIAL.

	Starboard.	*Port.*
Revolutions of main engines per minute	150.856	151.09
Revolutions, mean	150.973	
Piston speed, feet per minute	754.865	
Steam at boilers, gauge	166.06	166.06
Steam at engines, gauge	161.41	160.69
Steam at 1st receiver, absolute	76.76	76.53
Steam at 2d receiver, absolute	33.11	33.23
Vacuum in condenser, inches of mercury	23.984	23.638
Opening of throttle	8.	8.
Cut-off in fraction of stroke H.P.	.701	.686
Cut off in fraction of stroke I.P	.688	.699
Cut-off in fraction of stroke L.P	.694	.589
Revolutions of air and circulating pump	57.7	57.3
Revolutions of blowers per minute (four)	514.82	
Revolutions of feed pumps (four)	27.1	
Temperature, engine room	76.°94 F.	80° F.
Temperature, injection	38.2 F.	
Temperature, discharge	92.8 F.	
Temperature, feed	125.8 F.	

Temperature, fire rooms	84.2 F.	
Air pressure at ash-pans, in inches water	2.45	
	Starboard.	*Port.*
Mean forward pressure H.P. inboard, above atmosphere, uncorrected	128.02	129.22
Mean forward pressure H.P. inboard, above atmosphere, corrected	124.99	124.76
Mean back pressure H.P. inboard, above atmosphere, uncorrected	72.16	70.15
Mean back pressure H.P. inboard, above atmosphere, corrected	72.28	70.80
Mean pressure H.P. inboard, uncorrected	55.86	59.07
Mean pressure H.P. inboard, corrected	52.71	53.96
Mean forward pressure H.P. outboard, above atmosphere, uncorrected	133.83	131.60
Mean forward pressure H.P. outboard, above atmosphere, corrected	131.47	127.55
Mean back pressure H.P. outboard, above atmosphere, uncorrected	71.12	67.74
Mean back pressure H.P. outboard, above atmosphere, corrected	71.15	67.68
Mean pressure H.P. outboard, uncorrected	62.71	63.86
Mean pressure H.P. outboard, corrected	59.72	59.87
Mean forward pressure I.P. inboard, above atmosphere, uncorrected	50.86	52.62
Mean forward pressure I.P. inboard, above atmosphere, corrected	48.69	49.86
Mean back pressure I.P. inboard, above atmosphere, uncorrected	22.82	23.32
Mean back pressure I.P. inboard, above atmosphere, corrected	21.93	22.55
Mean pressure I.P. inboard, uncorrected	28.04	29.30
Mean pressure I.P. inboard, corrected	26.76	27.31
Mean forward pressure I.P. outboard, above atmosphere, uncorrected	49.96	50.67
Mean forward pressure I.P. outboard, above atmosphere, corrected	46.92	48.08
Mean back pressure I.P. outboard, above atmosphere, uncorrected	20.70	21.26
Mean back pressure I.P. outboard, above atmosphere, corrected	19.31	19.75
Mean pressure I.P. outboard, uncorrected	29.26	29.41
Mean pressure I.P. outboard, corrected	27.61	28.33
Mean forward pressure L.P. inboard, above atmosphere, uncorrected	7.87	8.71
Mean forward pressure L.P. inboard, above atmosphere, corrected	7.53	8.53

	Starboard.	*Port.*
Mean back pressure L.P. inboard, below atmosphere, uncorrected	8.48	7.56
Mean back pressure L.P. inboard, below atmosphere, corrected	8.11	7.97
Mean pressure L.P. inboard, uncorrected	16.35	16.27
Mean pressure L.P. inboard, corrected	15.64	16.50
Mean forward pressure L.P. outboard, above atmosphere, uncorrected	8.29	7.92
Mean forward pressure L.P. outboard, above atmosphere, corrected	7.77	7.72
Mean back pressure L.P. outboard, below atmosphere, uncorrected	7.89	7.19
Mean back pressure L.P. outboard, below atmosphere, corrected	7.44	7.46
Mean pressure L.P. outboard, uncorrected	16.18	15.11
Mean pressure L.P. outboard, corrected	15.21	15.18
Indicated horse-power H.P., uncorrected	510.32	529.34
Indicated horse-power I.P., uncorrected	492.54	504.98
Indicated horse-power L.P. uncorrected	730.02	704.68
Collective I.H.P. each main engine, uncorrected	1,732.88	1,739.00
Collective I.H.P. of both main engines, uncorrected	3,471.88	
Indicated horse-power H.P., corrected	483.56	490.24
Indicated horse-power I.P., corrected	467.00	478.61
Indicated horse-power L.P., corrected	691.85	711.54
Collective I.H.P. of each main engine, corrected	1,642.41	1,680.39
Collective I.H.P. of both main engines, corrected	3,322.80	
Aggregate equivalent mean pressure on L.P. cylinders	36.54	37.33
I.H.P. of air and circulating pumps	19.14	17.48
I.H.P. of blowers (four)	45.92	
I.H.P. of feed pumps (four)	20.49	
I.H.P. of dynamo engine (estimated)	7.76	
I.H.P. of steering engine (estimated)	2.50	
I.H.P. of above auxiliaries	113.29	
I.H.P. of main engine, air and circulating pumps	1,661.55	1,697.87
I.H.P. of both main engines, air and circulating pumps	3,359.42	
Total I.H.P. of both main engines and all auxiliaries	3,436.09	
Cubic feet swept per minute per total I.H.P. by L.P. piston	6.085	5.957
Square feet of cooling surface per I.H.P.	1.472	1.506
Ratio total cooling to total heating surface	1 to 1.657	
I.H.P., collective, per square foot of grate surface, (all machinery)	15.62	
Total H.S. ÷ I.H.P.	2.386	
I.H.P. per ton of all machinery for propelling, including water in same	10.07	
Coal used per hour, pounds	8,923.	

Coal used per hour, pounds per square foot G.S.	40.559
Coal used per hour, pounds per I.H.P., (all machinery)	2.597
Refuse per hour, pounds	805.
Refuse, per cent	9.

MAXIMUM PERFORMANCE.

13th period—1.30 P. M.	*Starboard.*	*Port.*
Steam at boilers, gauge	169.0	169.0
Steam at engines, gauge	162.0	160.5
Steam in 1st receiver, absolute	77.2	73.
Steam in 2d receiver, absolute	34.2	33.2
Vacuum in inches of mercury	24.12	23.75
Throttle	Wide open.	
Revolutions	152.0	151.8
Piston speed in feet per minute	760.0	759.0
Mean effective pressure H.P. inboard	52.71	53.02
Mean effective pressure H.P. outboard	61.10	59.27
Mean effective pressure I.P. inboard	26.76	27.04
Mean effective pressure I.P. outboard	27.61	28.46
Mean effective pressure L.P. inboard	15.64	17.08
Mean effective pressure L.P. outboard	15.67	16.31
I.H.P. of H.P. cylinder	494.92	485.91
I.H.P. of I.P. cylinder	481.74	479.69
I.H.P. of L.P. cylinder	722.29	753.37
Collective I.H.P., each main engine	1,698.95	1,718.97
Collective I.H.P., both main engines	3,417.92	
I.H.P. air and circulating pumps	19.10	19.72
I.H.P. main engine, air and circulating pumps	3,456.74	
I.H.P. blowers	45.92	
I.H.P. feed pumps	20.49	
I.H.P. dynamo engine	7.76	
I.H.P. of steering engine	2.50	
I.H.P. all machinery	3,533.41	
Revolutions of air and circulating pumps	60.	60.
Revolutions of feed pumps (four)	30.	
Revolutions of blowers (four)	544.5	
Air pressure at ash-pans, inches of water	2.7	
Cut-off H.P.	.70	.70
Cut-off I.P.	.70	.70
Cut-off L.P.	.70	.58
I.H.P. per square foot of G.S.	16.06	
Total H.S. ÷ I.H.P.	2.32	
I.H.P. per ton of propelling machinery and water	10.36	

The following table briefly compares the official trial results of the *Yorktown*, *Concord* and *Bennington*, sister ships.

It will be remembered that the sequence of cranks in the

Concord and *Bennington* differs from that of the *Yorktown*. For ahead motion the *Yorktown's* cranks follow in the order of H., I. and L., and the *Concord's* and *Bennington's* L., I. and H.

The *Yorktown* has the closed fire-room system of forced draft, and the *Concord* and *Bennington* have the closed ash-pit, Kafer system.

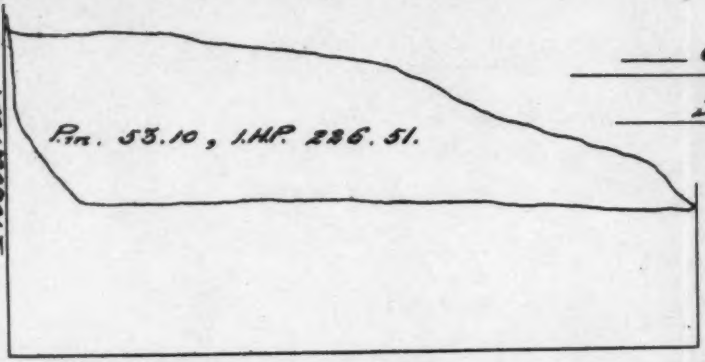
DATA OF MACHINERY AND RESULTS.

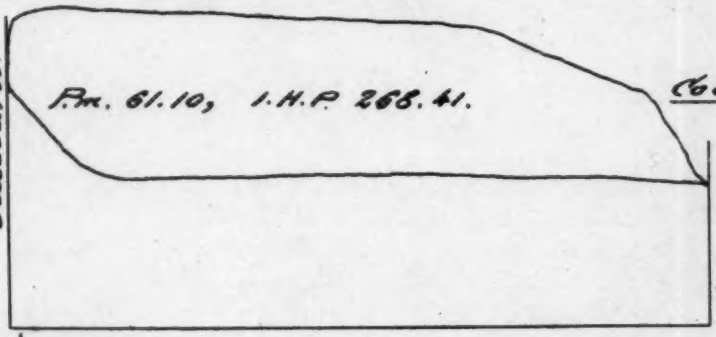
	Yorktown.	*Concord.*	*Bennington.*
Dates of trials	Feb. 13, 1889.	Jan. 13, 1891.	April 2, 1891.
Duration of trials (continuous)	4 hours.	4 hours.	4 hours.
Pitch of screw (twin screws)	12 ft. 6 in.	13 ft. 2.45 in.	13 ft. 8⅛ in.
Steam at boilers (pounds)	150.5	164.03	166.06
Steam at engines (pounds)	143.55	159.75	161.05
Steam at first receiver, pounds absolute	70.7	78.275	76.65
Steam at second receiver, pounds absolute	20.15	28.77	33.17
Vacuum in condenser, in inches	24.93	24.05	23.81
Revolutions of main engines	156.96	152.41	150.973
Temperature of injection, Fahrenheit	40.4	36.	38.2
Temperature of discharge, Fahrenheit	92.6	105.5	92.8
Temperature of feed, Fahrenheit	96.8	139.9	125.8
Air pressure. *Yorktown* in fire-room; *Concord* and *Bennington* in ash-pans, in inches water	1.25	2.292	2.45
Revolutions of blowers	757.	497.5	514.82
Revolutions of air and circulating pumps	121.75	51.15	57.3
Mean effective pressure H.P. cylinders, pounds	56.66	53.493	56.57
Mean effective pressure I.P. cylinders, pounds	34.19	29.596	27.50
Mean effective pressure L.P. cylinders, pounds	10.37	15.187	15.63
Indicated horse-power H.P. cylinders	1,015.17	928 742	873.80
Indicated horse-power I.P. cylinders	1,220.67	1,026.759	945.61
Indicated horse-power L.P. cylinders	969.44	1,358.802	1,403.39
Collective horse-power of main engines	3,205.28	3,314.303	3,322.80
Indicated horse-power, air and circulating pumps	118.79	27.328	36.62
Indicated horse-power, blower engines	52.03	34.774	45.92
Indicated horse-power, feed pumps	16.15	17.624	20.49
Indicated horse-power, dynamo engines	.....	8.000	7.76
Indicated horse-power, steering engines	.....	2.500	2.50
Aggregate horse-power, main engines and auxiliaries	3,392.25	3,404.529	3,436.09
Per cent. of horse-power of auxiliaries to horse-power of main engines	5.8*	2.7	3.4
Speed in knots, average four hours	16.14	16.8	17.5
Speed in knots, maximum	17.2	17.4	17.8
Contract price	$455,000	$490,000	$490,000
Premium	39,225	452.90	3,609
Total cost to United States	$494,225	$490,452.90	$493,609

* Omitting horse-power of dynamo and steering engines.

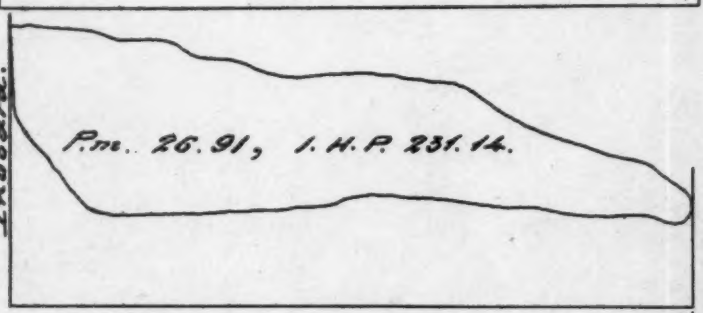
The indicator cards shown are for the period when the maximum horse-power was developed.

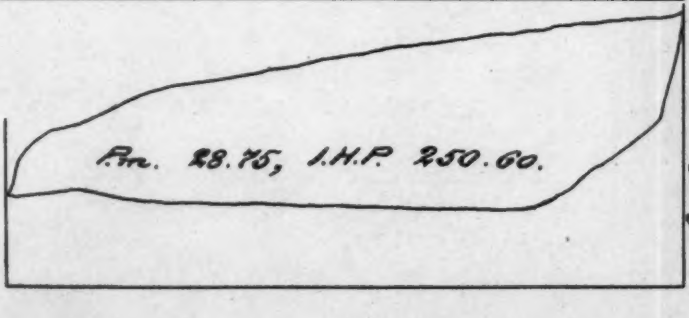
H. P. Cylinder.
Scale 40 lbs.





I. P. Cylinder.
Scale 40 lbs.





U.S.S. BEN

STARBOARD

Long Island

April 2, 1891,

Cards

Revolution

Vacuum

Collective I.H.P.
1698.95.

Steam Pressure
" "
" "
" "

NOTE

Cards show
correct

P.m. and
correc

NNINGTON. —

D ENGINE.

d Sound,

, 1.30 P.M.

s No: 13.

ons 152.

24.12.

P. of Engine.

5.

re at Boilers 169.

" Engine 162.

" 1st Receiver 77.2.

" 2nd " 34.2.

L.P. Cylinder.
Scale 18 lbs.

Inboard.
P.m. 16.30, I.H.P. 367.25.

Outboard.
P.m. 15.67, I.H.P. 355.04.

Vertical Feed Pump.
Scale 60 lbs.
27 double Strokes p.Min.

Bottom.
P.m. 76.37, I.H.P. 2.552.

Total I.H.P. 5.248.

Top.
P.m. 78.70, I.H.P. 2.696.

E:

ven without
ctions applied.

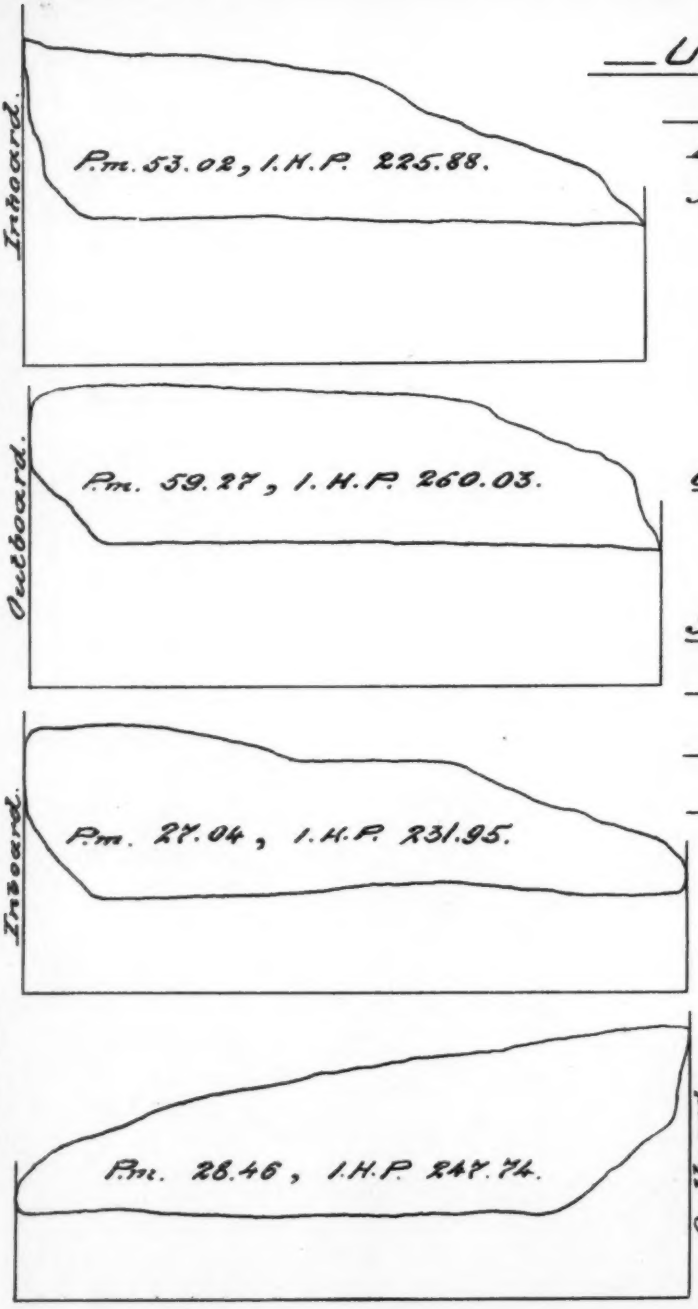
I.H.P. given with
ctions applied.

After Starboard Three-Cylinder
Brotherhood Blower Engine.

Lower Cylinder
Scale 80 lbs.

P.m. 37.07.
I.H.P. 5.48.

Revolutions 591.



U.S.S. BEN

PORT E

Long Island

April 2, 1891

Cards

Revolutio

Vacuum

Collective I.
1718.

Steam Pressu

" "

" "

" "

No

Cards st
co

P.m. and
with cor

NNINGTON. —

ENGINE.

rd Sound,

91, 1.30 P.M.

ls No. 13.

ions 151.8.

n 23.75.

I.H.P. of Engine

8.97.

ure at Boiler's 169.

" Engine 160.5.

" 1st Receiver 73.

" 2nd " 33.2.

NOTE:

known without

orrections applied.

d I.H.P given

rrections applied

L.P. Cylinder. Scale 16 lbs.

Inboard.

P.m. 17.08, I.H.P 384.32.

Outboard.

P.m. 16.31, I.H.P 369.05.

Forward

Air and Circulating Pump

Scale 40 lbs.

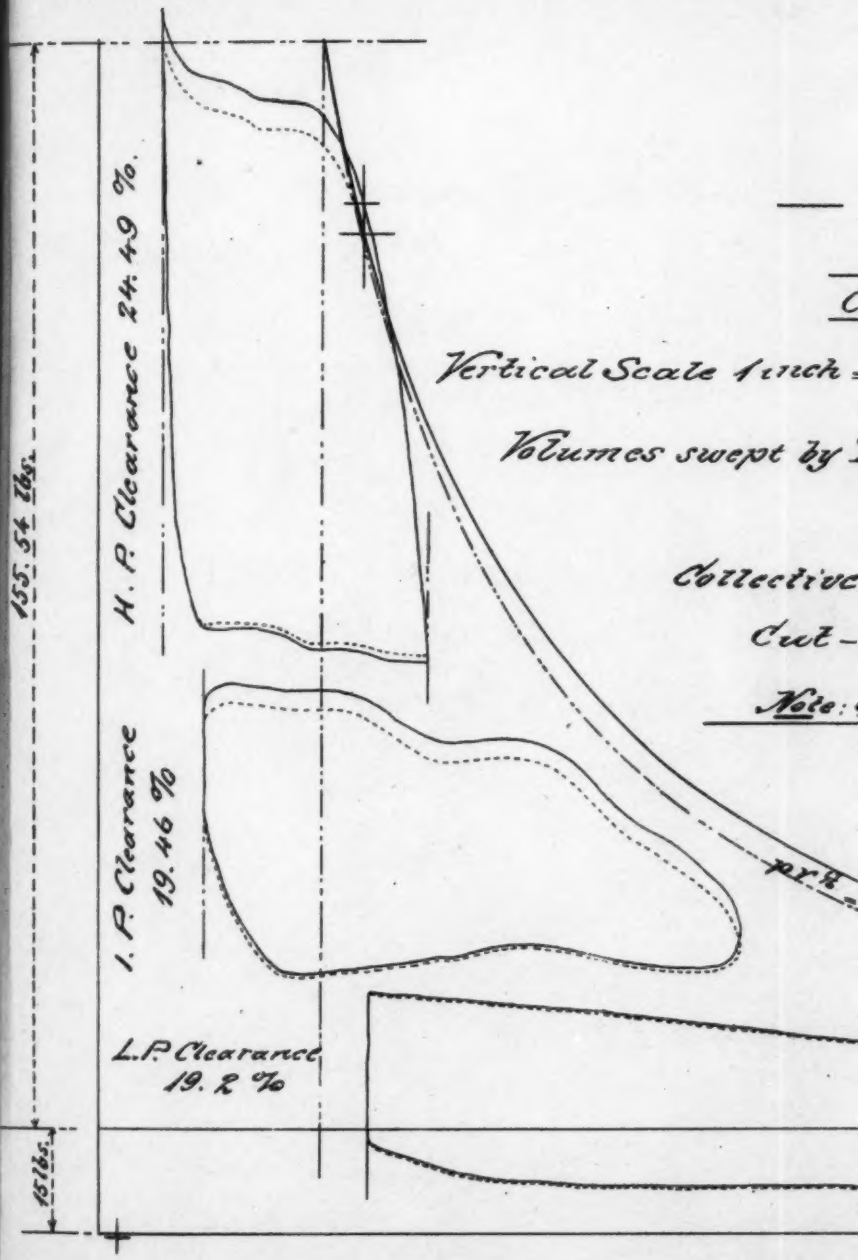
P.m. 35.23, I.H.P 9.62.

Inboard.

Revolutions 60.

Outboard.

P.m. 36.22, I.H.P 10.10.


155.54 lbs.
H. P. Clearance 24.49 %.
I. P. Clearance 19.46 %
L.P. Clearance 19.2 %
15 lbs.
Vertical Scale 1 inch =
Volumes swept by
Collective
Cut –
Note:

Long Island Sound, April 2, 1891.
1.30 P.M.

U.S.S. BENNINGTON.

PORT ENGINE.

Cards No. 13, inboard.

= 24 lbs.; Horizontal Scale 1/4 inch = 1 cubic foot.

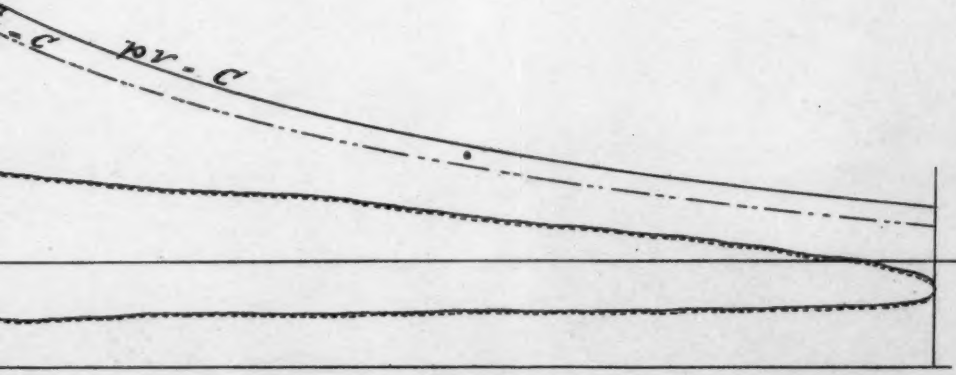
Pistons: H.P. 6.41 cu.ft., I.P. 12.95 cu.ft., L.P. 33.89 cu.ft.

I.H.P. 842.15.

I.H.P. of Engine 1718.97.

-off at .79 of Stroke

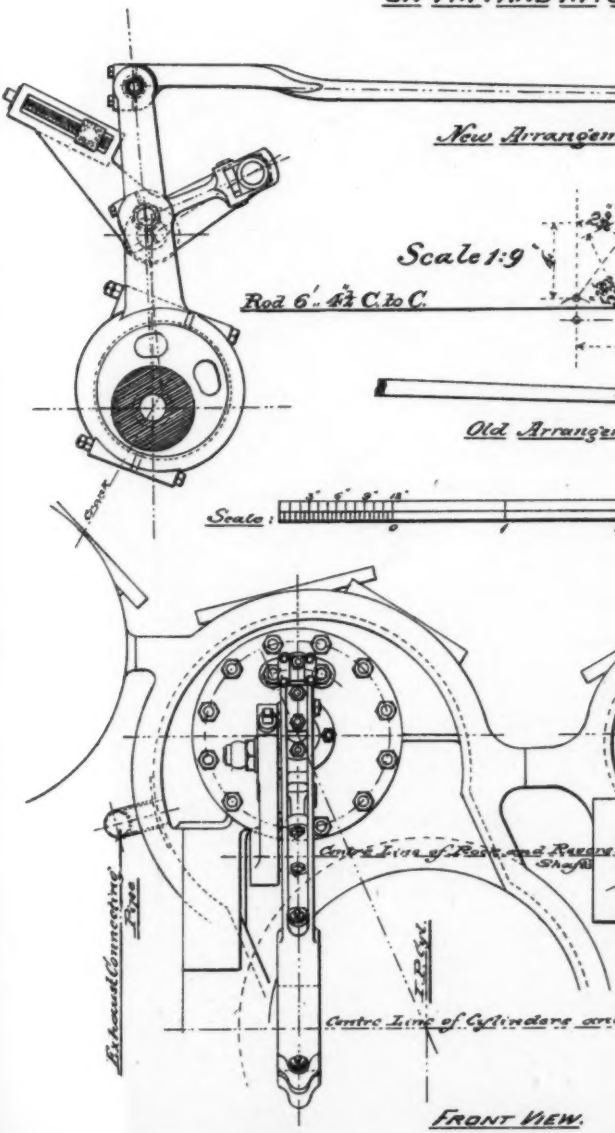
: Corrected cards shown in dotted lines.



U.S.S. BENNI

MODIFICATION OF MARS

ON H.P. AND I.P.C

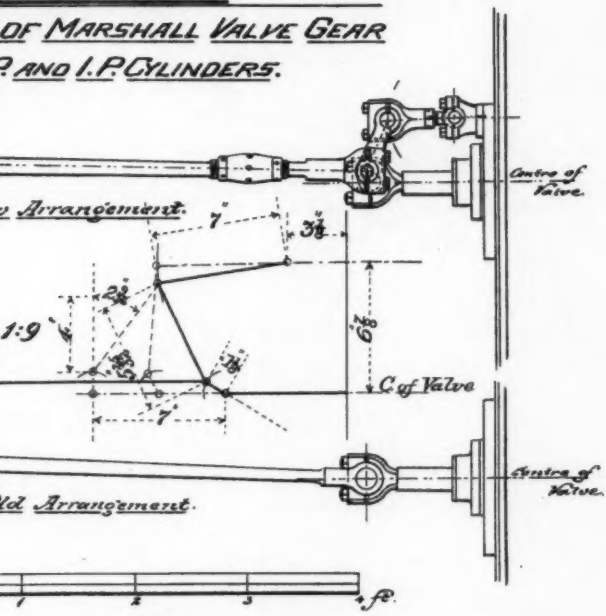


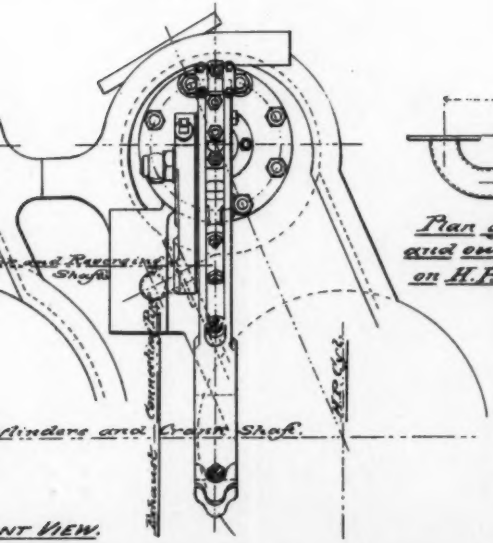
FRONT VIEW.

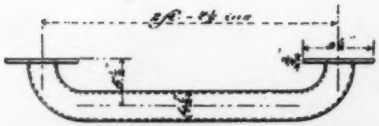
S. BENNINGTON.

OF MARSHALL VALVE GEAR

P. AND I.P. CYLINDERS.



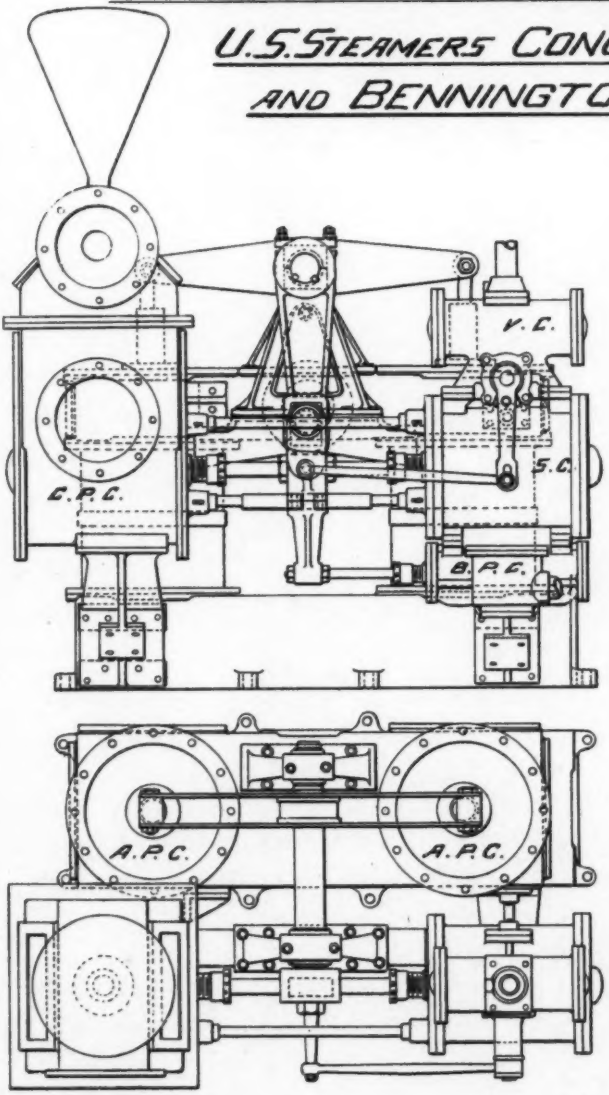




Plan of 4½" Pipe, connecting in- and outboard Exhausts on H.P. and I.P. Cylinders.

Air, Circulating & Bilg

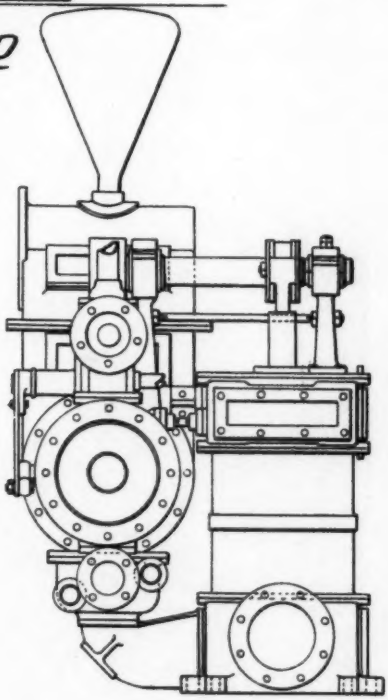
U.S. Steamers Concu
and Bennington



g & Bilge Pumps.

Concord

ngton.



V. C., Valve Chest, 6" Diam.

S. C., Steam Cylinder, 14" Diam.

C. P. C., Circulating Pump Cylinder, 18" Diam

A. P. C., Air Pump Cylinders, 18" Diam.

B. P. C., Bilge Pump Cylinder, 4" Diam.

-Stroke 12 inches.-

Scale: 6" 9" 3" 0 1 2 3 4 5 ft

XIII.

TABLE GIVING I.H.P. OF AUXILIARY MACHINERY IN PER CENT. OF I.H.P. OF MAIN ENGINES.

COMPILED BY ASSISTANT ENGINEER ALBERT MORITZ, U. S. NAVY.

	Charleston.	*Philadelphia.*	*San Francisco.*	*Newark.*	*Yorktown.*	*Concord.*	*Bennington.*
I.H.P. air and circulating pumps	*143.10	119 841	137.140	93 403	118.790	27.328	36.62
I.H.P. blowers	75.57	87.570	110.670	117.320	52.030	34.774	45.92
I.H.P. feed pumps	45.84	34.482	42.850	52.988	16.150	17.624	20.49
I.H.P, of all other auxiliaries	85.59	39.696	41.550	20.058	—	10.5	10.26
I.H.P. of all auxiliaries	350.10	281.589	332.210	283.769	186.97	90.226	113.29
I.H.P. main engines	6,316.06	8,533.180	9,580.72	8,582.303	3,205.28	3,314.303	3,322.80
Per cent. I.H.P. of aux. to I.H.P. main engines	5.54	3.3	3.46	3.3	5.83	2.72	3.41

* Including 6.94 I.H.P. of main bilge pumps.

XIV.

ECONOMIC MARINE PROPULSION.

By Chief Engineer John Lowe, U. S. Navy.

The purpose of this paper is to ascertain the relations which, in steamship propulsion, exist between the speed of the ship and the fuel which must be consumed to obtain that speed; and also to find the most economical rate at which that vessel can proceed.

It must be conceded that the most obvious and the most conclusive method is to try the ship at all desirable speeds; but the expense in time, labor and money is prohibitive; therefore a satisfactory method for calculating these matters, in these days of large ships and large coal bills, has become a necessity.

Many years ago, long before the question became vital, the writer published an article upon this subject, which he had the pleasure of seeing immediately republished in nearly all of the scientific journals of the day; since then, however, it has been almost forgotten, until by a notice written by Passed Assistant Engineer Bieg, U. S. N., in the Journal of the American Society of Naval Engineers, it was given new life, a fact evidenced by numerous requests for a copy, which it is best to comply with by writing a better paper, embodying increased experience with the subject.

Ordinarily speaking, the power required to propel a ship at any speed varies with the cube of that speed, and, incidentally, with the cube of the revolutions of the propeller which produces the speed. But the ratio between the speed of the ship and the revolutions of the propeller varies greatly with the weather; thus with a strong head wind the revolutions may be great and the speed nothing. For this, and for many other reasons, the

revolutions rather than the speed will be used as a basis for calculation.

There are two standpoints from which to study this question:

1. A vessel, notably a vessel of war, having a certain amount of coal on board, may desire economic propulsion, in order to make her coal carry her as far as possible; she would therefore proceed at such a rate as to make each knot cost as little as possible in coal; or, in other words, she would seek economy in fuel.

2. A merchantman, however, would seek economy of a commercial kind; she would therefore proceed at such a rate as to make each knot cost as little as possible in money; or, in other words, she would seek economy in money.

Consider economy in fuel first.

It is easy to understand, whether a vessel proceed fast or slow, or even if stopped altogether, that a certain quantity of coal must be consumed to supply auxiliary power and to maintain the temperatures of boilers, pipes, cylinders and other hot surfaces; and that this quantity is not a variable, but is a constant quantity, amounting to (q) tons per 24 hours.

To this must be added the real cost of propulsion, which, at the rate of one revolution per minute, amounts to (k) tons, and at the rate of (R) revolutions, to (kR^3) tons, per 24 hours.

Within this time unit therefore, the total quantity consumed will be

$$Q = (q + kR^3) \tag{1}$$

At the rate, therefore, of (R) revolutions the cost per day of each revolution is

$$\frac{Q}{R} = U = \frac{q + kR^3}{R}. \tag{2}$$

If now $\dfrac{dU}{dR} = \dfrac{3\,kR^3 - q - kR^3}{R^2}$ be placed $= O$,

then $R = \left(\dfrac{q}{2\,k}\right)^{\frac{1}{3}}$ and is the most economical rate possible. (3)

To obtain the constants (q) and (k) it is necessary to try the ship at two different rates, viz., at R and at R_1 revolutions, from

which is derived $Q = (q + k R^3)$, and $Q_1 = (q + k R^3_1)$, and therefrom, $k = \left(\frac{Q - Q_1}{R^3 - R^3_1} \right)$, and $q = (Q - k R^3)$ (4)

By this method, therefore, three most useful equations are obtained.

By (1) a curve is plotted showing coal consumption at all possible speeds.

By (2) a curve of endurance is plotted for all possible speeds.

By (3) the economic speed is found direct.

To apply this method to merchantmen, it is only necessary in these equations to substitute for the coal in tons its value in money, and to add to the constant (q) other constant expenses in money, such as keep of passengers, interest, insurance, and so forth. Since in the case of merchantmen (q) must be increased, a curious corollary arises, viz., the economic speed of a merchantman is greater than that of a man of war.

What has thus far been written is substantially the original method, which may be called the rigid method, to distinguish it from what follows, which may be called the provisional method.

Experience demonstrates, that under the circumstances usually attending the trials of our new ships, it is well nigh impossible to obtain correct data for more than one rate of speed. Nevertheless it is highly important to have some idea of what the future performance of that ship will be. To meet this difficulty the following method of finding the values of (q) and (k), from one trial only, has been devised. It is based upon the fact, that since there is a constant quantity of (q) tons consumed, even though the ship is stopped, therefore the power unit, within the time unit, costs (m) times more at the lower than at the higher speeds.

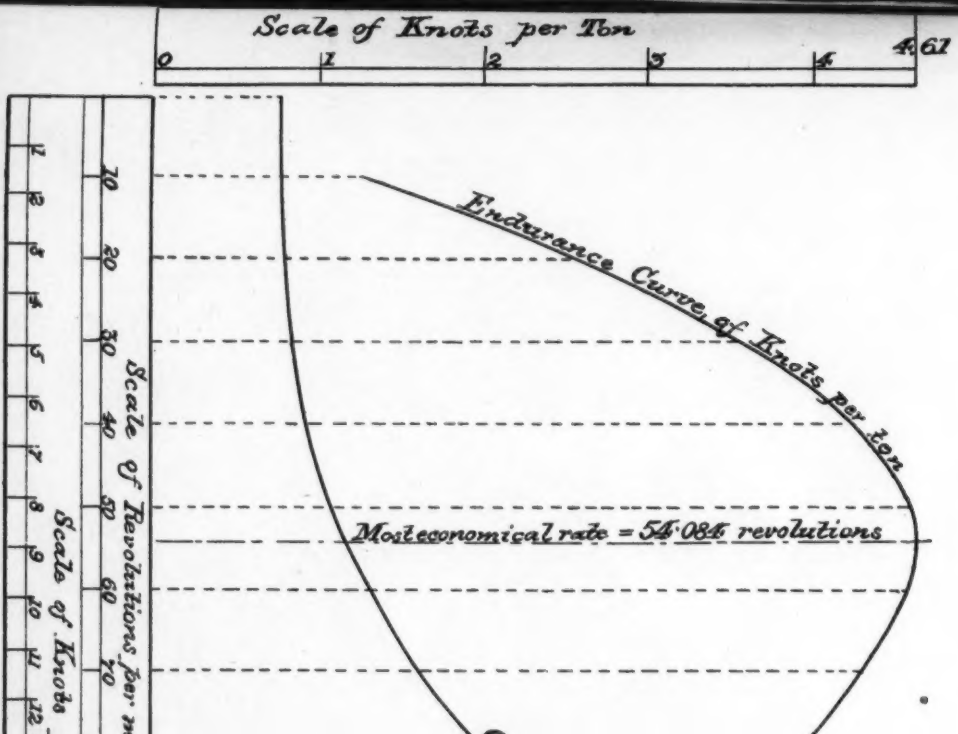
Let R = revolutions at which data is taken.

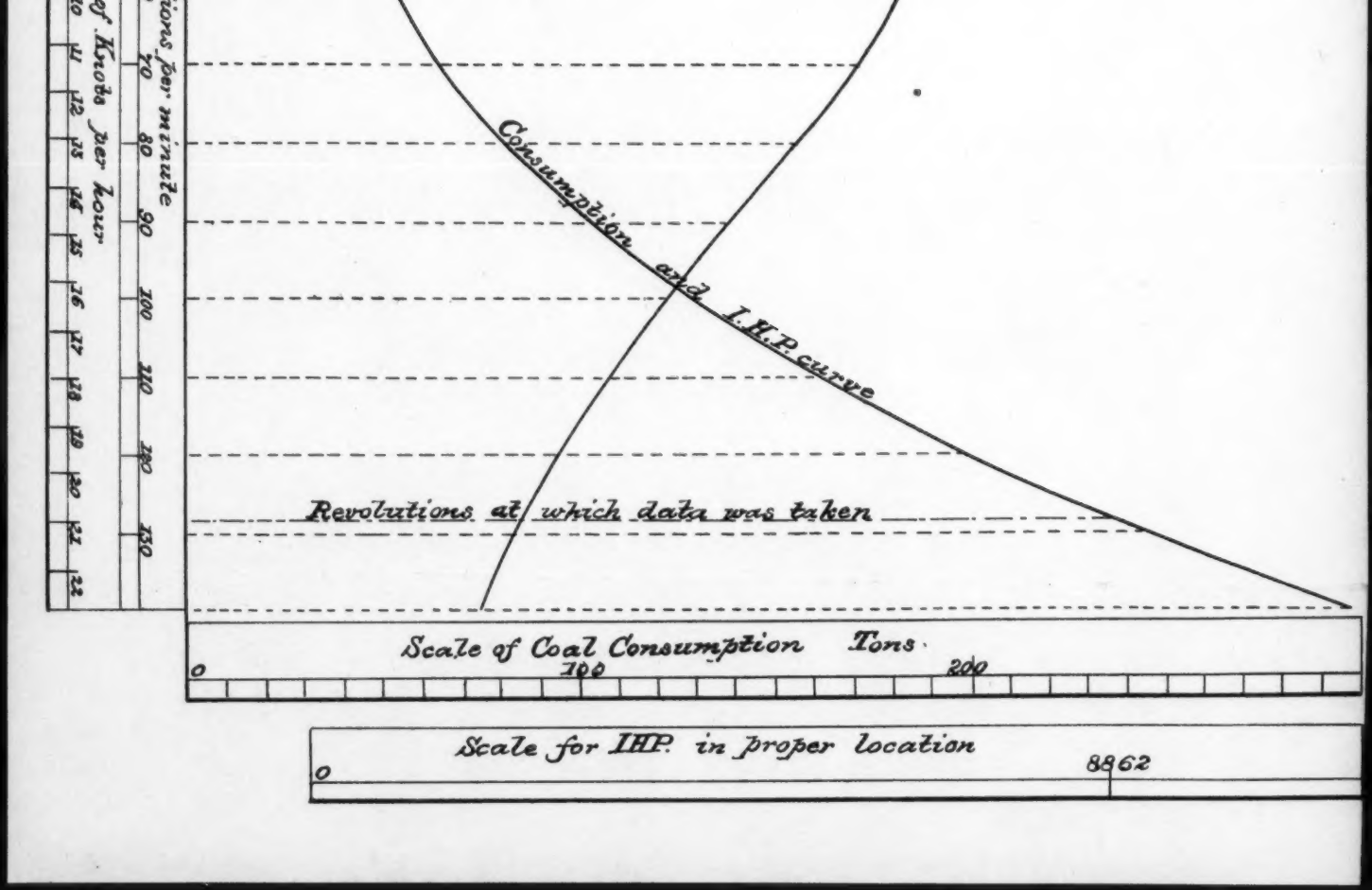
R_1 = revolutions at the economic rate.

$Q = a \times (I.H.P.)$ = total coal per day at (R) revolutions.

$Q_1 = ma \times (I.H.P.)_1$ = total coal per day at (R_1) revolutions.

Let also $(I.H.P.) = bR^3$, and $(I.H.P.)_1 = bR^3_1$,


Scale of Knots per Ton
0
1
2
3
4
4.61
Endurance Curve of Knots per ton
Most economical rate = 54·084 revolutions
Scale of Revolutions per minute
10
20
30
40
50
60
70
Scale of Knots
1
2
3
4
5
6
7
8
9
10
11
12


Consumption and I.H.P. curve
Revolutions at which data was taken
Scale of Coal Consumption Tons
0
100
200
Scale for IHP. in proper location
0
8862

Then $a = \left(\frac{q + kR^3}{bR^3}\right)$, $ab = \left(\frac{q + kR^3}{R^3}\right)$; and similarly, $mab = \left(\frac{q + kR^3_1}{R^3_1}\right)$.

But by equation (3) $R^3_1 = \frac{q}{2k}$; therefore, $mab = 3k$. (5)

Into (5) restoring the values $a = \frac{Q}{I.H.P.}$, and $b = \frac{I.H.P.}{R^3}$,

Then $k = \frac{mQ}{3R^3}$ and $q = Q - kR^3$. (6)

Now all these values are to be found in the data of one trial, except the value of m, which must be assumed; and because this method depends upon an assumption, therefore it is called provisional.

But this value may be derived from trials with other ships, and the results obtained by this method are more accurate than when taken from data in the least degree doubtful; in proof of which are given in the figure the performance curves of the *Newark*, calculated from the value of m found from data taken from the *Thetis*, than which two more dissimilar vessels could scarcely be imagined.

XV.

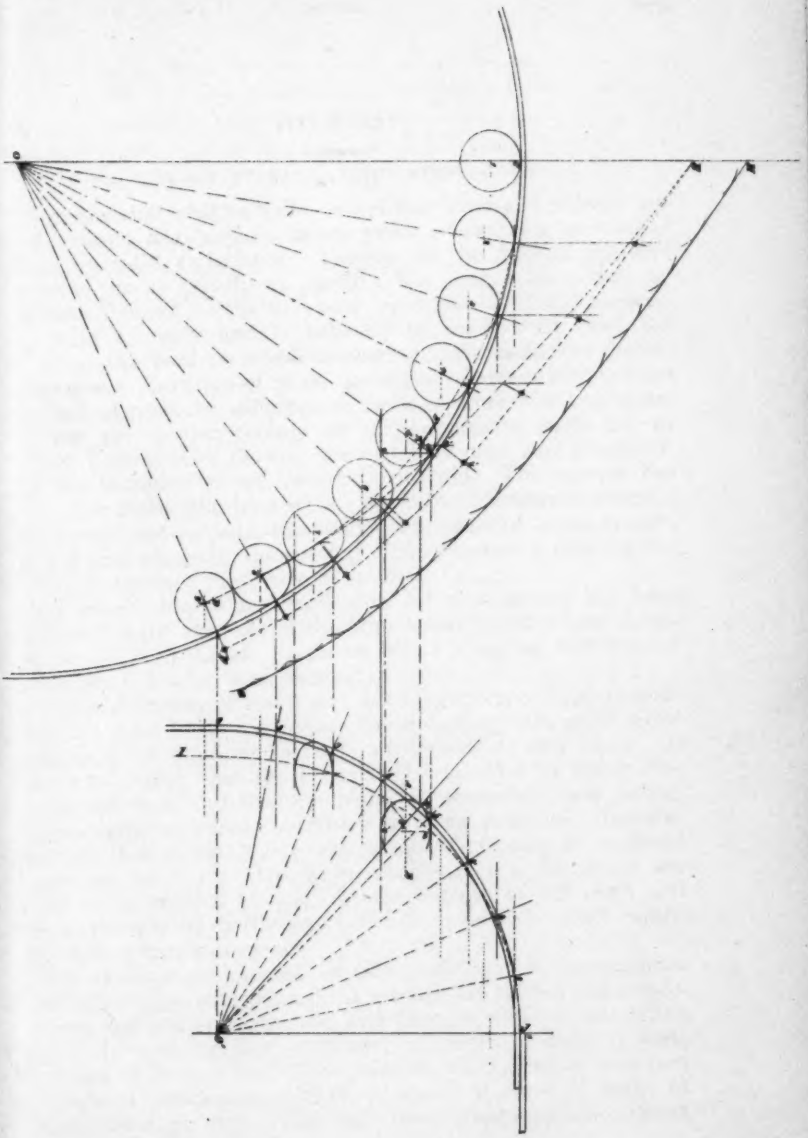
NOTE ON THE DEVELOPMENT OF CYLINDRICAL HEADS FOR STEAM BOILERS.

By Assistant Engineer H. G. Leopold, U. S. Navy.

The use of cylindrical heads for steam boilers has introduced a shell into the construction of the boiler which is somewhat difficult to develop.

The accompanying diagram illustrates a method which is both simple and accurate. In the diagram $O'K$ is the outer radius of the cylindrical head. The curved head is divided into any num-

ber of equal angular parts, in the present case eight. Taking any one of these points, as 5, it is projected over on the end view of the boiler where it intersects the inner radius of the shell plate at *b*. Through the point *b* a plane is passed passing through the center line of the boiler. This plane will cut an ellipse from the curved head, the projection of which on the end view of the head will be a circle coinciding with the view of the head. It will cut from the boiler shell a straight line, projected on the end view of the shell in 5 *b'*. The circle or curvature of the flanging will lie in this plane and be tangent to the beforementioned ellipse and straight line, and will be projected on the end view of the head in an elliptic arc tangent to their projections, as shown at *b* and *K*. Constructing all the points of tangency similar to *b*, we have the projection of the shell plate where it intersects the curved head *IJ*, and from this line we can readily develop the shell plate. Projecting *K* over to *K'*, we have the projection of the intersection of the flanging circle with the curved head *CD*. The curved head is then readily developed to *ED*. Erecting a perpendicular from *K'* to *k* where it intersects the flanging circle, we have the length of the arc of the flanging circle used. This arc is rectified and added to the development already obtained in a direction parallel to the trace of the plane *OK'*, and we thus obtain the development of the curved head to its intersection with the shell plate, as shown by *EF*. The width of the flange required for riveting is then added normal to the development already obtained. We then have the complete developed plate at *HG*. In developing the shell plate, the line *IJ* lies on the inner surface of the shell, and its development is slightly small, since in developing the shell the outer surface would be used; but this is on the safe side, and if desired, the outer line of intersection could readily be obtained from the diagram.



NOTES.

RED-HOT FURNACE CROWN EXPERIMENTS.

The question what to do in case of low water and red-hot furnace crowns has been for many years waiting for an answer based on solid experience. Putting on the feed strong and pumping up as rapidly as possible has always been met by opposition based on the following grounds: 1. It was universally held formerly, and is believed by many even now, that injecting the feed on red-hot heating surfaces led to the instantaneous liberation of great quantities of steam with sudden increase of pressure sufficient to cause rupture and explosion. 2. That the sudden cooling of the overheated parts led to violent contractions, causing the metal to rend and precipitating the calamity it was intended to avoid. The answer has been that, firstly, the heat stored up in the overheated material was insufficient to cause the sudden liberation of steam spoken of, and that, secondly, the cooling of the surfaces proceeded too slowly to produce those violent strains.

To set all doubts at rest, a series of experiments has been made under the auspices of the Manchester Steam Users' Association by their Chief Engineer, Mr. Lovington Fletcher, of which the following is an abstract:

While shortness of water has been heretofore made responsible for most boiler explosions, these experiments go to show that not more than one in six is attributable to this cause. It stands to reason that the material is weakened by being rendered red hot, and that the plates so weakened may subsequently give way under ordinary working pressure. But explosions due to this cause are usually fatal only in confined places, as on board ship, when people in the fire room are likely to be scalded to death by the outrush of hot water and steam, though the boiler may suffer comparatively small injury and remain firm in its seat.

The boiler experimented on (see plate) was of the ordinary Lancashire type, with plain furnace tubes, lap-jointed and single-riveted, and not strengthened with flanged seams or encircling rings. Length, 27 feet 9 inches; diameter of shell, 7 feet; diameter of flues, 3 feet. The material of the boiler was iron throughout: thickness of shell, $\frac{7}{16}$ inch; of ends, $\frac{9}{16}$ inch; of furnace flues, $\frac{7}{16}$ inch. The ends were stayed by four gusset

plates above the furnaces, while there were two at the front end and one at the back end below. The grates measured 6 feet by 3 feet, giving a total of 36 square feet. The heating surface is 828.5 square feet.

Boiler fittings.—At the front, 6 inches above the furnace crowns, were two feed valves with internal perforated dispersion pipes. Under ordinary conditions these pipes are straight, and are led along the side of the shell. The water is discharged back of the fire bridge, the first section or sections being blind. To make the test more trying in the present experiments, these pipes could be replaced by others, curved so as to bring the perforated length of 3 feet 9 inches over the center of the furnaces in front of the fire bridges. The pipes first described will be referred to as the *ordinary*, the last as the *experimental* feed pipes. At the sides of the shell near the front were fitted water gauges with glasses 18 inches long, so arranged that the height of water was recorded from a level of 16 inches above the furnace crowns to 16 inches below. There were two safety valves of 3 and 4 inches diameter. The water was injected by a feed pump 5 inches by 12, of a capacity of 5 cubic feet per minute, sufficient for three or four of the boilers experimented on. The following special fittings were provided: Screwed into the furnace crowns and secured by nuts were three gauge rods for indicating the movements of the furnaces. These rods were carried through stuffing boxes in the boiler shell, and their movements were indicated on a scale by wire cord connections. These rods were attached to the furnace tops at distances of 4 feet, 6 feet 9 inches, and 12 feet from the front end. For ascertaining temperatures, two thermometers with internal pipes 12 feet long were screwed into the boiler front, one 6 inches above the furnace crowns, the other 3 inches above the bottom of the shell.

For the protection of the observers a wooden hut was built on one side of the boiler, 33 feet distant. In it could be read the steam pressure and the height of water, as well as the movements of the furnace crowns, and from it could be controled the feed and blow.

I. *Observations while getting up steam.*—While getting up steam from cold water the temperatures of the water near the top and the bottom were taken at short intervals, and showed great differences. As this is a point enlarged on in Mr. Leonard's paper in this JOURNAL, it is unnecessary to dwell on it here. The movements of the shell were measured by three cross-pieces, fixed at the ends and near the middle in such a manner as to be unaffected by the brickwork. These movements were shown to

be very small. The extension of the shell was measured by a trammel, and amounted to $\frac{3}{8}$ inch. The movements of the furnace crowns are shown by the upper portions of the diagrams between the times 2.20 and 3.56 p. m. (See plate.) The maximum upward hogging amounted to over $\frac{1}{2}$ inch at a point 12 feet from the front end. This hogging of the furnaces is bound to exert strain on the boiler ends, and the two following points should be noted:

a. The ends should have a certain degree of elasticity, freedom of movement; for this reason the flues must not approach too nearly to the shell, nor must the gusset stiffeners approach too nearly to the flues.

b. It is inexpedient to tie the furnace flues to the bottom of the shell near the middle of their length with a view to supporting them. The support is unnecessary, the tie objectionable.

To bear out the results as to temperature differences in different portions of the boiler while getting up steam, Mr. Fletcher has experimented on other boilers of the same type and provided with Galloway tubes. The results obtained were similar, and it was shown that the circulation induced by the Galloway tubes did not seem to extend to the part of the boiler beneath the flues at the grates, *i. e.*, toward the front. The average results obtained while getting up steam were:

1. Boiler filled with cold water (about 60° F.), temperature difference 250°.

2. Boiler filled with hot water (about 150° F.), temperature difference 180°.

From these experiments the following conclusions were drawn:

1. Water near the bottom of the boiler is of much lower temperature than near the surface.

2. This temperature difference causes considerable strain in the plates and seams.

3. Boilers should therefore, if possible, be filled with hot water.

4. Getting up steam should proceed as slowly as possible, especially after the boiler has been cleaned, or when a new boiler is first used.

5. The stop valve should be opened as slowly as possible to avoid as much as possible a general disturbance of the water.

6. The feed pipe should discharge just below the water level.

Opening the boiler stop valve rapidly may lead to injury to the boiler in this way: The release of pressure tends to raise the water in the middle, below the valve; the consequent depression

of the surface elsewhere brings the hot water at the top in sudden contact with the cooler metal below, and causes strains.

II. *Experiments with red-hot furnace crowns.*—The total number of experiments made was thirteen, changes being made from time to time to ensure accuracy. The following are the characteristic tests:

A. *Trial at atmospheric pressure.*—The safety valves being wide open and the fires in good condition, water was blown out until it had fallen 16 inches below the top of the furnace crowns or 2 inches above the level of the fire bars. The safety valves were then shut, and 14 minutes after the water had begun to leave the furnace crowns the feed was turned on through both *experimental* pipes. In $\frac{3}{4}$ of a minute the pressure rose from 6 pounds to 27 pounds, after which it gradually fell. In $13\frac{1}{2}$ minutes the pressure was again reduced to 6 pounds, and in 20 minutes the water reached the top of the furnaces, the pressure being 4 pounds.

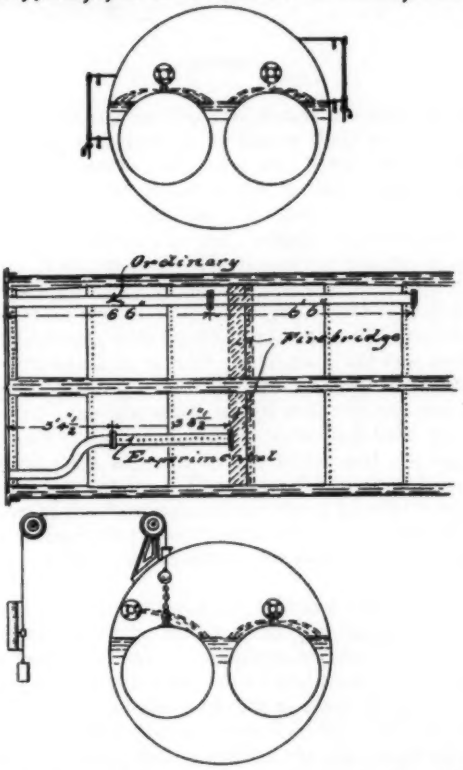
Examination proved that the furnace flues had been overheated, the left flue having developed two blisters. The plates at the ring seams above the fires were severely sprung, and the tubes had become oval, the greater distortion occurring in the right hand furnace, 7 feet 6 inches from the front end. The difference in the diameters was found to be $3\frac{1}{2}$ inches. There were no signs of rents or cracks. The movements of the furnaces are shown by the lower part of Figs. 2, 3 and 4.

B. *Trials at pressures above atmospheric pressure.*—Difficulty was experienced in determining the proper time to inject the feed, as direct observation of the furnaces was out of the question. A fusible disc was therefore secured to the top of the furnaces, and a rod screwed into this and carried through a stuffing box in the shell. Due to the jamming of this rod in its stuffing box the melting of the disc passed unnoticed, and 10 minutes after the water had left the top of the furnaces, and 6 minutes after it had been brought down to within 3 inches of the level of the fire bars, the right-hand furnace commenced to come down. The feed was turned on at once. The furnace rent at the first ring seam above the fire, the opening measuring about 3 feet circumferentially by 12 inches wide at the middle. Through this the water and steam rushed with great violence, scattering the coal lying in front of the fire in all directions, but the boiler was not moved in its seat nor otherwise injured. The left-hand furnace was bulged down 1 inch at the crown for a portion of its length. The pressure carried was 40 pounds.

To prevent a recurrence of the jamming, the gauge rods were

Fig. 1.

Arrangement of feed pipes at trials under atmospheric pressure.



Arrangement of feed pipes at pressures above atmospheric.

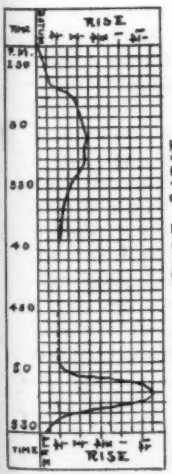


FIG. 2.

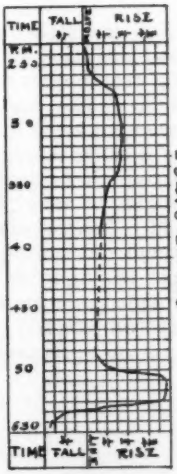


FIG. 3.

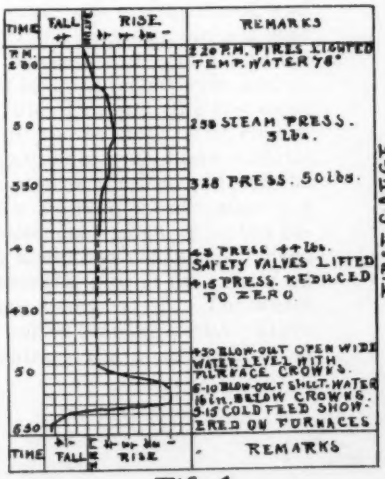


FIG. 4.

connected with the fusible discs by means of chains, so that they could be moved occasionally to insure their easy working. It was furthermore decided to close the blow-out tap when the water had fallen to the level of the furnace crowns and allow any further drop to proceed by evaporation. The experimental internal feed pipe above the left furnace was removed and replaced by the ordinary one. The following nine trials were conducted in this way:

Steam pressure was run up until the safety valves lifted, and kept at that pressure, which varied from 25 to 31 pounds. Water was blown down to a level with the furnace crowns, and the fires then worked up into good condition. The feed was turned on in the different experiments 5, 10, 15 and 17½ minutes from the time the furnace crown commenced to be laid bare, the *ordinary* feed pipe being used in some of the trials and the *experimental* pipe being used in others. The water fell as much as 3 inches below the top of the furnaces, laying them bare to a width of 20 inches; yet during all these trials there was no rise of pressure noticeable when feed was injected, nor did the overheated plates show signs of rending.

It was apparant from these trials that the fusible discs of lead and tin used could not be relied on to give uniform indications. It was therefore decided to supplement the foregoing experiments by another in which zinc discs and lead and tin plugs were used, all connected by chains and rods to recording devices. The zinc discs were distant about 4 feet 6 inches from the front end, the lead plugs about 5 feet 8 inches, the tin plugs about 7 feet, or just at the fire bridges. Before making the experiment it was ascertained that, with the method of securing the discs and plugs adopted, tin was melted before the plate was visibly heated, lead melted when the plate was dull red, the zinc disc did not melt until a cherry-red heat had been reached. In addition to the discs and plugs a strip of lead 4 feet long, 1½ inches wide, and $\frac{1}{16}$ inch thick, was laid across the middle of each of the first eight belts of plating to show the extent of the heating. The experiment was conducted as the preceding ones. Eighteen minutes after the water had left the furnace crowns the lead plug of the left flue melted; after 21 minutes a tin plug fused; after 23½ minutes a zinc disc melted. The water had fallen $3\frac{5}{8}$ inches below the top, exposing the flues to a width of 21 inches. Feed was turned on through the *experimental* pipe at the rate of 4½ cubic feet a minute, the temperature being 60° F. The steam pressure was 28½ pounds, the safety valves blowing freely. There was no rise of pressure; on the contrary, the pressure fell from

28½ to 26 pounds in 2½ minutes. Examination revealed the following: The crowns were discolored for a width of 12 inches and a length of 8 feet and 9 feet, in the left and in the right furnace respectively. The overlaps of the first seven ring seams in each furnace were sprung at the crown, but the furnace tubes were practically unaltered, though the right hand furnace showed three shallow bulges, the greatest depression being ¼ inch. All the fusible plugs were found melted, and of the lead strips five were found melted on one furnace and six on the other. A lead strip was found melted on the right hand flue 7 feet beyond the fire bridge.

The experiments lead to the following conclusions and observations:

Feeding cold water on red-hot heating surfaces does not result in sudden liberation of steam in volume too great to find escape through the safety valves without great rise of pressure; it does not result in rending the plates subjected to this treatment. It may therefore be argued that in the event of shortness of water the best thing to do is to turn on the feed. In all the experiments made with the safety valves blowing, there was no rise of pressure whatever, which would go to show that with the engine running the feed could be turned on with advantage, as it would tend to lower the pressure, restore the water level, cool and invigorate the furnace plates, and give the attendant time to draw the fire. Injecting the feed with one safety valve shut, the pressure rose from 6 to 12 pounds in 1¼ minutes; with both valves shut, it rose from 6 to 27 pounds in ¾ of a minute. It would seem, therefore, that with the engine standing still, injecting the feed on the overheated and thereby weakened plates might, in consequence of even a slight rise in pressure, precipitate an explosion, which might not have happened had the fire been promptly hauled. However, it is at least a question if, the safety valves being set to blow freely, it would not after all be advisable to put on the feed, especially as in the experiment the feed was showered directly on the heated metal, which is not the case in actual practice. The experiments are not, however, considered conclusive on this point. A point to be noted is the time it took to blow down the boiler through a blowout tap 2½ inches diameter, with a pressure of 40 pounds. It took 4 minutes to blow the water from 6 inches above the furnace crowns down to their level, and 4 minutes more to blow down to about 3 inches above the fire bars. The discharge pipe was about 90 feet long. With a shorter pipe the discharge would have been more rapid. Ten minutes after the water had been brought

down to the level of the furnace crowns, the right-hand tube collapsed. With the full pressure the time would have been shorter.

Finally, it may be asked: What would have been the result of making the experiment under a higher pressure of steam, say 80 pounds to the inch? A furnace tube worked at such a pressure would have been strengthened with flanged seams or equivalent devices. It could then have been dealt with at 80 pounds more safely than the experimental boiler at 30, the furnace tubes of which were not strengthened by encircling rings. Had the experiments been conducted at a higher pressure, say 50 pounds, it is doubtful if the furnaces would have stood the heavy fires for 23½ minutes after the water had left the furnace crowns. If not, the plates would not have been as hot as they were, and the test would not have been made so complete, as the hotter the furnace crowns the greater the amount of steam which would be generated on the introduction of the feed.

ON THE CONSTRUCTION OF BOILERS ADAPTED TO FORCED DRAFT.

[Abstract of a paper read before the Institute of Naval Architects by Mr. A. F. YARROW.]

The paper is an examination chiefly into the causes of leaky tubes. It is an eminently practical one, and of great interest, dealing as it does with the constructions characteristic of the locomotive boiler as built by Mr. Yarrow, and showing how they are borne out and justified by reasoning and experiment.

Workmanship.—Without good workmanship and material trouble must be anticipated with boilers working under forced draft and at high pressures.

Quality and condition of tubes.—They should be of the very best material procurable, ductile and well annealed at the ends, perfectly straight, or if curved, all curved exactly alike, so that that the strain will come equally on all. The thickness of the tube where it is expanded should be the same all around, or the expander will not set the metal out equally. The outside of the tube ends should be free from scale or oxide. If polished and greased to keep them bright, the grease should be removed before inserting in the tube plate.

Method of expanding the tubes.—The taper of the expander used should correspond exactly with that of the hole in the tube plate, and if the latter is parallel, the taper of the mandrel and of the rollers of the expander should be the same, but opposite. The rollers should project a little beyond the plate to form a slight shoulder on the tube inside, insuring a tight fit and good

holding power. Mr. Yarrow also uses a roller which forms a slight bead on both sides of the tube plate. When expanding, it is recommended to expand not more than three or four tubes in one spot before shifting to a remote one. In this way the strain is more uniformly distributed over the tube plate, which suffers less in consequence. Mr. Yarrow does not believe in screwing the tubes into the tube plate, as it does not go to the root of the evil, and makes retubing difficult. A thin copper ferrule slipped over the end of an iron or steel tube and expanded with it has been known to reduce the leakage, due to the copper expanding more than the adjacent material.

Stay tubes.—They have been discarded by Mr. Yarrow. If used, they should not be thicker than the ordinary tubes, only thickened up where they screw into the tube plates, the object being to keep all tubes equally elastic.

Holding power of ordinary tubes.—Experiment showed that a 2-inch tube expanded into a steel plate had a holding power of 8 to 12 tons. In a locomotive fire box instanced this gave a safety factor of 20 without the aid of stay tubes.

Ferrules.—Ferrules do not affect the leaky tube question materially. They do not reach the root of the evil. They are of use, however, in contracting the opening of tubes exposed to the fiercest heat.

Water space stays.—It is most important to arrange these in a manner to secure freedom of movement for the inside fire box, which is intimately connected with freedom of the tube plate from external strains. The author instances a case where a boiler gave much trouble from leaky tubes. After eight unsuccessful attempts to pass the trial, the row of stays next the tube plate was made yielding by the stays being made to pass through stuffing boxes with a nut outside. When the boiler was being worked, these nuts were clear of the glands; every time the furnace door was opened, they approached them; when the boiler was cold, they bore hard on them. There was no more trouble from leaky tubes. In consequence of this experiment, the first row of stays is never spaced nearer than 7 inches to the tube plate flange, and in large boilers this row is left free to move.

Elasticity.—This is an important requisite in a boiler. The tube plate flange is thinned at the turn, to make it flexible and to keep the temperature difference on the fire and water side a minimum at the double thickness.

The water spaces should not be cramped, otherwise the stays will give trouble. These are turned down between the plates, to make sure that all bending occurs here and prevent moving the stay in the plates.

Hollow stays.—To facilitate repair and renewal of stays where several boilers are used side by side, a hollow stay has been designed, which can be inserted and made tight from one side. In a 1-inch stay a $\frac{1}{2}$-inch hole is drilled nearly all the way through, and a $\frac{3}{8}$-inch hole for the remainder. The stay is screwed in from the fire box and made tight by drifts of different sizes to fit the two ends. Experiment showed that a 1-inch stay with a $\frac{1}{2}$-inch hole was as strong as a $\frac{7}{8}$-inch solid stay.

Tube spaces.—Mr. Yarrow recommends a clear distance between tubes of 2-inch diameter in boilers burning from 80 to 100 pounds of coal per hour per square foot of grate of 1 inch with $\frac{7}{8}$ inch as a minimum. He attributes the poor success of some water-bottom locomotive boilers to the circulation induced around the fire box resulting in depriving the tube sheet of water.

Length of tubes.—The length of the tubes should be of such proportion to their diameter as will insure the necessary elasticity. For this reason large tubes or short ones are objectionable, as they are too rigid.

Alteration of tubes when raising steam.—An experiment was made to show this. Rods were inserted in a tube near the water level, midway of the nest, and at the bottom. These rods were fixed at the end next the fire, and in the middle of the length of the tube. As the water became heated the upper tube was bent, as shown by the movement of the free end of the rod. After a while the second rod showed movement likewise, and finally the bottom one. They all continued to move, showing that the extension of the tubes had caused them to become curved, until the steam pressure had risen to 10 or 15 pounds, which appeared to be sufficient to separate the tube plates enough to straighten out the tubes. This experiment shows the necessity for making the tubes elastic.

Distortion of boiler while raising steam.—The longitudinal extension of the shell was measured at the top, at the bottom, and at the water level. The greatest difference in the extensions recorded was .8 millimeter, that at the water level being greater than that at the top by this amount when steam was just forming. Mr. Y. recommends filling the boiler quite full, and allowing the cold water to flow out at the bottom as steam is being raised.

Air pressure.—The greater part of the resistance of the air and gases through the boiler is in most cases due to that offered by the tubes. High air pressures and long tubes go together, as well as light pressure and large and short tubes. For this reason the latter boiler, being the more rigid, may give trouble

where the former will not. In fact, what may be a high pressure for one boiler will be a low one for another. It is suggested, therefore, that rather than limit the air pressure it would be a better plan to leave that with the designer and limit the rate of combustion instead. It can then be ascertained what air pressure corresponds to that rate of combustion, and a correct limit of air pressure be determined for that particular boiler.

Grease.—No grease should gain access to the interior of the boiler.

Starting new boilers.—New boilers should not be at once subjected to their full working pressure, but be broken in gradually, so as to allow the different parts to accommodate themselves without undue strain. Very frequently tubes are found to leak on cooling down. If this is of small extent, it is best to leave them alone instead of unnecessarily punishing them by re-expanding.

Elasticity of tube in tube plate.—When a tube is expanded into a tube plate, it is slightly increased in diameter, as is also the hole. The metals are not only in contact, they press against each other, the tube tending to become larger, the hole smaller. This was shown by experiment. The actual collective elasticity of the tube to expand and the plate to contract was found to be $\frac{5}{1000}$ and $\frac{7}{1000}$ for steel tubes and plates, and $\frac{10}{1000}$ for copper. If now, the boiler being under steam, the furnace door be thrown open, letting in a rush of cold air, the tubes being thin are cooled faster than the plate. They will remain tight only so long as the chilling does not more than balance the collective elasticity of the tube and plate. If the chilling goes beyond this point the tube will leak. If the tube plate is thin, so that it will contract faster, difficulty from this cause will be avoided. It is important, therefore, to make this combined elasticity as great as possible. A simple way is to make the tubes a driving fit in the tube plates.

Thin tube and thick tube plate.—To ascertain the effect of heating and cooling tubes in a tube plate, experiments were made. A $6\frac{7}{16}$-inch tube $\frac{1}{16}$ inch thick was expanded into a 2-inch plate. Around the tube plate some thin sheet steel was fitted, forming a tank, this was filled with water which was then alternately heated and allowed to cool. After eight heatings the tube leaked, and after eighteen it leaked so badly that the experiment had to cease. On examination the end of the tube was found crushed. The explanation is as follows: The water being heated, the tube being thin was heated much more rapidly than the plate. Its expansion was prevented by the rigid plate, and the metal of the tube permanently crushed.

Thick tube and thin tube plate.—The experiment was repeated with an $\frac{1}{8}$-inch tube and a $\frac{7}{16}$-inch tube plate and no leakage resulted after heating and cooling forty times. From these experiments it is argued that the more nearly the tubes and tube plates approach in thickness, the less will be the chances of leakage. Hence, as the tubes cannot be thickened up and retain their elasticity, the tube plates must be made thinner. Steel tubes and copper tube plates have been used with success, but copper or brass tubes or steel tubes with copper ends are preferred. The latter plan secures the advantage of copper in keeping the tubes tight in the plate while having the same rate of expansion as the boiler shell. With steel tube plates steel tubes are nearly always used and there is no reason for using any other. What has been said about the necessity of keeping the tube plate as thin as possible applies more particularly to steel tube plates, as the greater thermal conductivity of copper makes it possible to use heavier plates with safety.

Tendency of tube plates to curve.—To make this clear an experiment was performed. A steel tube plate 18 by 18 inches and $\frac{3}{4}$ inch thick had thirty-six tubes expanded into it. Around the edges of the plate very thin sheet steel was secured, forming the sides of a tank. This was filled with water and heat applied, the conditions being made to correspond as nearly as possible with those obtaining in a boiler. It was shown that the tube plate, strongly heated on one side and kept comparatively cool on the other, assumed a curved shape, this being indicated by the deflection of uprights secured to the plate. On the basis of this experiment it is safe to say that the curvature of the tube plate of the boiler of a first-class torpedo boat would be no less than $1\frac{3}{8}$ inches. Now in a boiler the tube plate is not free to move, and it remains to investigate what happens.

Reducing size of wheel tire.—To illustrate what is to follow, I take the method adopted for reducing the size of a wheel tire. The tire is heated red hot and increases in diameter; it is then immersed half its width in water. This cools the lower half, which contracts in consequence, but cannot do so without pulling with it the upper half which is still red hot. This upper half, partly reduced in diameter by force, will on cooling be reduced still further, and be made permanently smaller in diameter. The operation is now repeated in an inverted order until the tire is made as small as desired.

Molecular strain on the tube plates through the two sides being subject to different temperatures.—The tube plate of a boiler is in a state very much like the wheel tire. One side of it in con-

tact with the furnace heat tends to expand, but is kept from expanding freely by dint of its connection with the cooler metal on the water side. The result is a compromise, the metal on the water side expanding as much as possible and permanently stretching the cooler material. Now, when the inner surface is suddenly cooled, as by the inrush of cold air on opening a furnace door, it tends to contract, but is held back by the metal on the water side, whose temperature is not sensibly affected. The result is a fresh compromise. The outcome of these successive compromises is a distortion of the plate: the holes are drawn out oval, some in one direction, some in another. The foregoing may be made more plain, perhaps, by considering that the curvature spoken of above has taken place and that every time the furnace door is opened the tube plate straightens out. The result of this continued bending and straightening would certainly end in permanently damaging the plate. Now, the plate is not in a boiler actually alternately bent and straightened, but what does take place is its equivalent.

Distortion of hole in plate repeatedly heated on bottom side.—A plate was so secured as to be kept flat, only being allowed to move longitudinally. Water was kept on the upper side, while the bottom side was alternately heated and cooled by blasts of hot and cold air. The plate was $1\frac{1}{2}$ inches thick, and had in it a hole $3\frac{7}{8}$ inches in diameter. After being heated and cooled fifty times, the hole was found to have been distorted, the hole at the upper surface having been longitudinally extended $\frac{20}{1000}$ inch and contracted transversely $\frac{2}{1000}$ inch; the hole on the bottom surface having been altered much less.

From what has been said it follows that thin tube plates are a necessity if tubes are to be kept tight, not only because the metal in them is less likely to be permanently stretched, but also because the plate and tubes expand and contract more or less in harmony.

Practical conclusions.—From the foregoing it is argued that tube plates should not exceed $\frac{1}{2}$ inch in thickness. A thickness of $\frac{3}{4}$ inch is sure to give trouble with forced draft. A thickness of $\frac{3}{8}$ inch is recommended, for Mr. Yarrow holds that this thickness is ample for strength, no part of the boiler being more securely supported, while $\frac{3}{8}$ inch is all that is necessary to make a good steam joint. In this connection attention is drawn to the fact that tube plates are likely to fail after a time, due to a carburisation of the steel at the high temperatures and a consequent brittleness.

Plastering tube plates.—This can never be regarded as any-

thing but a temporary device, and offers no solution of the difficulty. When some of the cement falls off, the heat is concentrated on those spots, leading possibly to strains more severe than if the whole surface had been exposed.

Setting out of tube plates.—With regard to spacing the tubes either in horizontal and vertical rows or zig-zag, Mr. Yarrow favors the latter plan. The number of tubes that can be brought within a given area is about the same, but the distance between tubes is greater in the latter case; in an example given $\frac{7}{8}$ inch and 1 inch respectively. With tubes spaced in rows there are two lines of least section, while with the zig-zag arrangement there are three; but in the latter case there is more metal left in the lines of least section, and this is the thing that tells.

Comparison of copper and steel for tube plates.—It has been shown that one of the chief reasons why tubes leak is that the holes become distorted, due to the strains set up in the plate by the differences and the change of temperature. These strains are proportional to the curvature assumed by the plate. To compare these, a plate strip of copper and one of steel were arranged to have water on one side while the other side could be heated and cooled. By means of two uprights and crossbars a pointer was made to indicate the amount of curvature. It was found that steel deflected much more than copper and was very much more sensitive to changes of temperature. The coefficient of expansion of copper is greater than that of steel in the ratio of 3 to 2, but its conductivity is greater also in the ratio of 6 to 1; so that the case stands 12 to 3 in favor of copper. For these reasons Mr. Yarrow prefers copper for his fire boxes, and points to the fact that every locomotive engineer in Great Britain favors copper, while in the United States, where steel fire boxes are commonly used, more trouble is had with leaky tubes. The only argument against copper is its greater cost, but this being in marine work only from 2 to 4 per cent. of the total cost of the complete vessel is not a great item.

Galvanic action.—This, if it exists, is not of sufficient importance to outbalance the advantages possessed by copper. In proof of this is submitted that foreign governments, after having had experience with copper fire boxes, specify them now.

Elasticity the element of success.—Every design is more or less of a compromise, but one thing is clearly necessary, and that is to insure a design conforming to the requirements of changes of form due to changes of temperature. It also points to the importance of adopting only the highest classes of material so as

to insure ample elasticity. To secure all this, however, people must be prepared to pay the price which these requirements entail, and herein lies one great difficulty, for in the present day many firms, and some governments, in their struggle for cheapness, have in reality to pay for their false economy by failure.

Conclusion.—Concluding, the author hopes that in the light of more intelligent boiler design forced draft will come to be looked upon, not as an unreliable and dangerous device, but as one of the greatest improvements of modern times.

In the discussion which followed the reading of the paper Mr. Durston, Engineer-in-Chief of the Navy, said: A locomotive boiler might be successful in a torpedo boat, where there was only one, while it might fail if used in groups. It was essential to the satisfactory working of such a boiler that the water level should be maintained as nearly constant as possible, which was impossible with a number of boilers supplied by one or two feed pumps. The beginning and end of all the trouble with forced draft was the overheating, not the heating, of certain parts, notably of the tube plate and tube ends. He laid this to want of space between the tubes and consequent impaired circulation. About expanding tubes Mr. Durston held that the bead inside the tube plate did no good, and instanced a case where tubes so expanded had leaked worse than others expanded with straight rollers. Stay tubes, he said, were used to guard against the consequences that would ensue if the tubes became red hot. He thought that locomotive boilers, given ample space, and treatment similar to that such boilers receive on shore, would do as well on board ship as on land. He believed that air pressures should be limited; if a boiler suffered injury with 3 inches, it would suffer more with 4. The speaker gave it as his opinion that a vacuum in the smoke box was better than a plenum in the fire room. Referring to the experiments of Mr. Martin on the discarded locomotive boiler of the *Polyphemus*, he said that when worked with a pressure in the fire room the tubes were all choked up in twelve hours, while they were quite clear at the end of thirty-six hours when worked by suction in the smoke box. Mr. Durston ended by saying that forced draft was wanted in the Navy now only for steaming in the tropics; and he instanced a ship in which 10 per cent. of the tubes had been removed, and there was no failure in the production of steam and no trouble from leaks.

Mr. Fothergill argued against beading the tubes. He said that the tube plates should be rigid and elasticity in the tubes provided by corrugations near one end. He did not think that

the boiler of a locomotive with 8 inches of vacuum in the smoke-box and 2 inches of wind pressure was in the position of a boiler worked with a pressure of 10 inches in the fire room. The locomotive boiler was very much better off than the torpedo-boat boiler, when the furnace door was opened. His own experience in forced draft was, that pressures of $\frac{3}{4}$ inch were safe and advantageous, but that with $1\frac{1}{2}$ inches much risk of leakage was incurred.

Mr. Morcom instanced a case where a boiler worked well so long as the water was propelled toward the tube plate by a screw rigged for that purpose, but failed when it broke down. He also spoke of a case where a locomotive boiler with a wet bottom that gave trouble from leakage had been improved by blocking up the passage to the space below the fire box by a baffling plate.

Mr. Thornycroft held that one reason why tube ends gave trouble was on account of the thermal resistance offered by the joint between the tube and tube plate.

Mr. Marshall held that leaky tubes did not result from too much rigidity, but from the fact that plates were overheated in the attempt to crowd too much heat through them, and from want of proper circulation. He recommended deeper combustion chambers. Mr. Normand had been very successful with his boilers, and his success was largely due to the hanging bridge, which kept the direct impact of the flame off the tube plate. Staggering the tubes in the tube plate he considered bad. He had found it was better to make the greater distance vertical.

A few comments on Mr. Yarrow's paper from the *Engineering News* will be of interest. Mr. Yarrow mentions the fact that in the United States locomotive fire boxes and tube plates are made of steel, and says that some trouble is had with leaky tubes. On this point the paper mentioned says: The thickness adopted for tube plates is from $\frac{3}{8}$ to $\frac{1}{2}$ inch. Mr. Yarrow's experiment showing that steel is distorted more than copper, when subjected to heating and cooling, is incomplete in that it takes no account of conditions as they exist in practice. Let his plates be covered with thin scale, and see how much difference he will find in the conductivity. There is no special trouble in this country with leaky tubes. As far as cost goes, the copper fire box costs in England, all allowances made, four times as much as the steel one, and does not appear to last any longer.

SOME DETAILS IN MARINE ENGINEERING.

[Abstract of a paper read by THOMAS MUDD before the Institution of Naval Architects.]

Boilers.—The ordinary method of uniting the heads and shell of a boiler, which consists in leaving the shell straight and flanging the heads, is open to several objections: It is difficult to make a tight job where the laps of the sheets forming the heads are riveted to the shell, and where the flange is fitted over the longitudinal butt straps of the shell plates. To make a perfect job the heads and shell should be a driving fit. If the head is too small, a pucker is bound to result when the work is riveted up, which pucker it is impossible to overcome with the caulking tool, as it moves away before it. If the head is too large, it tends to open the seams of the shell and leakage is apt to result through the exposed end of the butt. Some adjustment is given by leaving one of the seams of the head open until the flange joint is riveted up, but with the flanges keyed on by the butt straps of the shell, not much adjustment is possible. The rivets are spaced radially of necessity, rendering them inaccessible and difficult to replace in the water spaces around the furnaces.

To overcome these difficulties the writer has, since 1884, followed the plan outlined below, which had been recommended and used when iron was the common boiler material, but had been discarded when steel came into extensive use. The cross-seams of the heads, which are left perfectly flat, are welded at the ends for a distance of about 18 inches, as are also the butts of the shell plates. The latter are then flanged and the flat heads riveted on, the rivets being longitudinal and easily accessible. There are some points to be noted in connection with this method of construction. The writer has satisfied himself by actual experience that mild steel is perfectly well able to bear the strains incidental to this mode of construction. The weld is perfectly sound, as is evidenced by the fact that flanging takes place after the weld is made, without starting it. As regards flanging, the author has flanged 1,000 heavy boiler plates without having to return to the makers more than two plates that showed slight surface tearings on being flanged. He is of opinon that local heating, as long as it is confined to the edges, does not have any injurious effect, but he believes in annealing the flanged plates before riveting up. These are therefore placed flange downward in an annular furnace, heated to a red heat, and allowed to remain and cool with the furnace. The rivets in the end seams are brought in tension instead of in shear, as is ordinarily the case. The author sees no disadvan-

tage in this, as far as strength goes, and points to his experience to corroborate the statement that no leakage results. The back head is riveted up first with a hydraulic riveter, snap heads inside and out. The front head is riveted up by hand, snap heads inside, deep countersinks, almost through the plate, on the outside. Both ends have double-riveted joints, the rivets being spaced zig-zag. The author has lately been following the practice, where the head consists of three separate sheets, of connecting the upper and lower ones by narrow strips welded to each, completing the circular disc, and riveting up. The middle sheet, the tube plate, is then laid on, the rivets at the flange passing through three thicknesses of metal, the flange of the shell, the connecting strip, and the tube plate.

Boring stern frames.—To insure the stern frames being bored true, the author follows the following plan: The boring bar, which is hollow, is introduced. At its after end, which is truly bored in line with the axis of the bar, a carefully constructed telescope is slid in. This telescope is provided with cross hairs and proper focal adjustments, so that the horizontal and vertical marks indicating the intended position of the center of the crank shaft, marked on a board erected on the engine seating, can be easily seen. The bar being in position when the sight is taken may be adjusted from side to side or up and down, until the user of the telescope is satisfied with the sight; it is then only necessary to make all fast and commence work.

The machining of crank shafts.—The writer calls attention to the fact that many specifications for marine machinery call for turning up the shaft body after the sections of which it is made up are finally bolted together. This, of course, insures that the main shaft journals are all accurately in line, but gives no guarantee that the crank pin axes are parallel with the shaft axis or that the planes of the coupling faces are perpendicular to the shaft axis. The former, however, is just as important to the smooth running of the machinery as the correct alignment of the journals, while the latter is a necessity if, as is ordinarily the case, the shaft sections are to be made interchangeable and reversible in the simplest possible manner.

To secure all these qualities, the writer proceeds as follows: Each section is finished separately; the crank pin is finished before shrinking the parts together, the body parts being left rough turned. The section is then fixed in the lathe on the main body part centers, and accurately set by the pin—that is to say, the shaft is revolved into four positions, top, bottom, right and left. In these four positions a spirit level is laid on

the pin, and the shaft moved in the centers until it will revolve in such a way as to show that the axis of the pin is truly parallel with the axis on which the shaft is revolving. The shaft is then completely finished. Its main bearings are turned, the peripheries of the couplings turned accurately to a dimension, and their faces surfaced down. When the shaft sections have been thus treated, they are set together by the peripheries of the couplings in V blocks, the bolt holes are bored, and the shafts bolted together. The shaft is then brought as a whole again into the lathe, not, however, to be turned, but simply for examination, to prove the accuracy of the work. If the shaft is out of truth, *i. e.*, if the main bearings are not running truly on one axis, the fault is obviously in the bolting together. To take a cut off any part would make the shafts no longer duplicates.

Piston packings.—The author begins by saying that the number of piston packings that have been patented is legion, but that some engineers, after having tried one form or another in their high-pressure cylinders, have gone back to the Ramsbottom rings. These make a pretty cylinder, but they wear fast and leak steam. The author states that a form of packing which is well suited for the low or the intermediate pressure cylinders may fail in the high, but that the converse of this is not necessarily true. The joint between the packing rings and the piston flange, junk ring, and tongue piece cannot be made so tight as to prevent the admission of steam into the space back of the rings. The pressure existing here will, of course, vary with the pressure in the cylinder and the accuracy of fitting, but may, with good workmanship and 150 pounds in the cylinder, be taken at say 100 pounds. This pressure forces out the packing rings with great force, and it is a mistake to increase it by springs. Indeed, in a vertical engine, the packing rings not overrunning the bore so far as to receive a blow from the steam forcing them into the recess, the piston is better off without any springs whatever, leaving the packing rings to accommodate themselves to the cylinder independent of irregularities of motion of the piston.

The principal office of springs in the piston packing should be to reduce the pressure between it and the cylinder wall, or, what is more easily accomplished, to minimize its effects. The author has, proceeding on this principle, patented and successfully used a packing described below:

Two packing rings are used, of a cross-section 2 inches square, for all sizes of cylinders from 18 inches to 80, the greater stiffness demanded by the higher pressures in the high-pressure

cylinder being given by the reduced diameter. The width of two inches is adopted to give a wide bearing surface between the piston flange and the follower, which latter is set down hard. The rings are thus kept from being forced out by the steam by the friction. The pressure applied through the follower is regulated to suit the steam pressure. Helical springs, $2\frac{3}{16}$ inches in length and 1 inch in diameter, are let into holes in the lower surface of the upper ring and the upper surface of the lower ring, and their compression furnishes the pressure between the rings and the follower and piston flange, which is increased by the steam between the rings. The distance of these springs apart on the circumference and the amount of compression given them is found sufficient to meet all the differences required between high-pressure pistons and low-pressure pistons. One of these springs is usually inserted tangentially at the joint of each ring with just sufficient pressure to keep the ring from sliding in the cylinder by its own weight. To provide against the emergency of the rings wearing down due to the pressure on the springs being released from any cause, in which case the single tangential spring might prove insufficient, holes are bored into the inner side of both rings, so that the springs may be inserted and made to act in the manner of ordinary piston springs. The author states that out of 250 pistons of all pressures that have been fitted with these packing rings there has never yet been one to renew, and none, to the author's knowledge, has worn open more than $\frac{1}{8}$ inch at the joint.

Cylinder construction.—The author calls attention to a cylinder arrangement adopted by him, which, while it gives a plain and compact exterior, easily lagged, makes a very efficient engine. By this arrangement the H.P. cylinder is in the middle, and the valve chests of the intermediate and low-pressure cylinders are placed between the cylinders. In this way the radiating surface is reduced to a minimum. The high-pressure cylinder is jacketed and the receivers of the other two cylinders are carried around it, so that the jacket, although of small extent, is very efficient, radiating through both the inside and outside walls. It has been shown during the trials of the S. S. *Iona*, conducted by Prof. Kennedy, that this jacket was condensing 4.55 per cent. of the total feed water. This same engine was found to give on a 16 hours' trial one I.H.P. for 13.35 pounds feed water per hour.

In the discussion which followed the reading of the paper Dr. Kirk and Mr. Fothergill endorsed the author's methods as regards boiler work and the fitting of crank shafts and piston

rings. Dr. Kirk has largely followed the same practice as regards boiler work for the last twelve years. He thought the cost was about the same as in thinning the corners of flanges and fitting them in the ordinary way. The practice of turning up long crank shafts made of pieces bolted together led to bad work, because the shafts deflected under their own weight, and the truth with which the bearings were turned depended on the accuracy of the bearing set up in the lathe. He also believed that there existed an atmosphere of steam on the back of the packing rings exerting a pressure equal to about half the working pressure in the cylinder. He had some years ago made some experiments on Ramsbottom rings to test their tightness. Two pistons were bolted together on one spindle, steam was let into the space between them, and they were run by an eccentric in an open cylinder at from 120 to 150 revolutions per minute. When one of the pistons was moving down so as to be pressing against the steam, it leaked; when it was coming up, the steam following, it remained tight. The success of the Ramsbottom rings depended much on their stiffness and on being turned originally a little larger in diameter than the cylinder. With a piston rod guided top and bottom float rings are required. When the piston rod does not go through the cylinder cover the piston must be guided by the junk ring or similar devices.

Mr. Fothergill said he had several of Mr. Mudd's engines and seven of his boilers working at 160 pounds under his supervision, and they had proved very satisfactory. In ordinary boiler practice, in order to get the tight fits required for high pressures, the end plate, when flanged to fit the shell, should be turned. The arrangement described by Mr. Mudd had also the great advantage of affording better facilities for repairs when it was necessary to keep the boiler low.

Mr. Milton said that the method adopted by Mr. Mudd for boiler construction got over some difficulties, but introduced others. The principal of these was the necessity of annealing the large and heavy shell plates, a critical and delicate job. Mr. Mudd had spoken of the imperfect fit due to the flange never being free from pucker. The same was still true when the shell plates were the ones flanged. Besides, the author still had the same difficulties to contend with in fitting the furnace mouths. A further objection was found in the fact that the method described called for deeper water spaces around the furnaces, thus necessitating greater diameters of shell to accommodate the same heating surface. Mr. Milton thought the method adopted for boring stern frames a good one, but equally good results were

obtained by means of sights and battens, which method had the further advantage that by means of the same sets of observations the position of every intermediate bearing could be fixed. He approved the method for fitting up crank shafts, but added that the coupling bolts should be made strictly interchangeable. This was accomplished by boring the holes in each flange from a properly constructed block.

In replying to these remarks Mr. Mudd said that the unevenness of the flanged surface was not a matter of such great importance in the method pursued by him, as the pressure exerted by the rivets was enough to draw the end plates into the puckers. It would, however, make a better job to face up the flanges in the lathe. As to fitting the furnace mouths, the difficulties here were not great, as the metal was thin and more readily worked. It was customary to put the furnaces in slack and expand them afterwards with a plying hammer or otherwise. Mr. Mudd was in the course of experimenting with a hydraulic expander to get over the plying. He conceded that the water spaces were greater in his boilers, but he considered this no drawback, a good feature rather. Mr. Milton had said that to be consistent he should have to weld both ends of the seams of each course of shell plating; there was, however, no necessity for doing this as the open butt was protected by a cover strap. Mr. Mudd agreed as to the desirability of having the coupling bolts of crank shafts interchangeable, but thought that too much stress had been laid on this point. When a shaft section had to be changed to another position it would probably be found that the holes were somewhat damaged, in which case it would be found necessary to dress them out with a rose-bit or rimer.

BOILER DEPOSITS.

The following points are taken from a paper on the subject read by Prof. Vivian B. Lewes, before the Institution of Naval Architects:

Constituents of scale.	River.	Brackish.	Sea.
Calcic carbonate	75 85	43.65	0.97
Calcic Sulphate	3.68	34.78	85.53
Magnesia hydrate	2.56	4.34	3.39
Sodic chloride	0.45	0.56	2.79
Silica	7.66	7.52	1.10
Oxides of iron and alumina	2.96	3.44	0.32
Organic matter	3.64	1.55	trace.
Moisture	3.20	4.16	5.90
	100.00	100.00	100.00

Prof. Lewes makes the presence of cylinder oil in the boilers

responsible for most furnace collapses. This oil is carried over by the steam even though its boiling point is far above the temberature of the steam. Experiment showed to what extent the peposit of oily material on the heating surfaces was concerned in allowing excessive heating of the plates and retarding the heating of the water. A clean iron vessel was taken, and a known volume of water placed in it and heated by a carefully regulated Bunsen flame, the water being raised to the boiling point in 10 minutes; the experiment was repeated with the same result, and the vessel was then lined with a coating of deposit from the bottom of the boiler that had collapsed, and rendered binding by admixture of a small trace more valvoline. This coating was laid on $\frac{1}{16}$ inch thick, and the experiment repeated, using the same flame and the same quantity of water with the result that it took 15 minutes before the boiling point was reached, showing that even if no damage resulted to the plates there was a large waste of fuel. To determine the temperature to which the iron of the vessel had been raised, the water in the various vessels was brought to the boiling point, and the clean bottom quickly applied to various substances of different igniting and melting points.

With a clean vessel, sulphur did not melt, temperature below 239° F.

Coated vessel, sulphur melted, but did not inflame, temperature above 239° F., below 482° F.; gun cotton ignited, temperature above 392° F.

The fiercer the heat applied the more marked became the overheating. With an atmospheric blowpipe the temperatures were:

Clean vessel, sulphur did not melt, temperature below 239° F.

Coated vessel, gun cotton ignites, temperature above 392° F.; tin melts, above 444.4° F.; sulphur ignites, above 482° F.; lead melts, above 633° F.; zinc melts (just), above 793.4° F.

On replacing the atmospheric burner by an oxy-coal gas flame there was no difficulty in fusing a hole into the bottom of the vessel, which was of thin wrought-iron, showing that a temperature of 2732° F. had been attained. It is therefore manifest that with the fierce heat existing in a boiler furnace, given an oily deposit only $\frac{1}{16}$ inch thick, the plates will be readily heated to a temperature at which they are totally unable to withstand the boiler pressure, and a collapse of the furnace crowns must follow.

The boilers of a steamer are instanced plying between Liverpool and Boston, whose furnaces got out of shape. These boil-

ers were filled with fresh water in port, and as a rule, the water on the voyage, which lasted about 12 days, was made up by the use of about 70 tons of fresh water. During the last voyage sea water was used for this purpose. Every 4 hours while under steam 4 pounds of soda crystals were put in the hot well, making about 2 cwt. during the run, the total capacity of the boilers being about 81 tons. When in port, the boilers were allowed to cool down, the water was run off, and they were swept down with stiff brushes and washed out with a hose before filling with fresh water. Seven pints a day of valvoline (which was examined and found to be a pure mineral oil), were used in the cylinders. No trouble occurred with the boilers until five voyages before the final collapse, when some of the furnaces began to creep in; they were stiffened with rings and stays, and on the succeeding voyages the whole of the furnaces got out of shape one after another. Examination of the scale and deposit from various parts of the boilers showed from 3.23 to as high as 50.2 per cent. of organic matter and oil. The scale found on the furnaces showed the smallest amount, but for this Prof. Lewes accounts by saying that on the plates becoming red hot the oil was burnt out.

The oil carried into the boiler with the feed water remains suspended near the water surface in the shape of drops, or, if there is much of it these combine into a scum. If the boiler is to be blown down, the surface blow should be started first, and this scum got rid of, otherwise it will fall with the water and settle on the heating surfaces. Prof. Lewes considers that the greasy deposit is more likely to take place with *fresh water* in the boilers than with *salt*, as, owing to the lower specific gravity of the former, the scum can settle faster. Its deposit is hastened by the presence of calcic sulphates and other solids separating from the water, to which it adheres and by which it is borne down. To overcome both these evils, Prof. Lewes proposes two things: first, to get rid of as much of the oil as possible by passing the feed water through a long tube filled with pieces of clean coke of about the size of a walnut; and, secondly, to precipitate from the sea water its scale-forming ingredients, yet leaving its specific gravity high enough, due to the presence of sodic chloride, etc., to prevent the ready settling of any entrained oil. A form of *precipitator* has been experimented with, and the boiler fed with water from it for a month was found, on opening, perfectly clean, the surfaces looking as if they had received a coating of whitewash.

The process employed was to add to the sea water a known

quantity of precipitator powder, consisting chiefly of soda ash, and having done this in a closed vessel, to heat the mixture by blowing into it waste steam until a pressure of 5 to 10 pounds was created. Under these circumstances practically all the calcium and magnesium salts separate from the water and are easily got rid of by filtering it under pressure into the hot well. The attempt had been made to heat the water by blowing the steam through a coil; this was found insufficient. It was also discovered that the reaction was hastened by heating the water just to the boiling point before adding the powder. The precipitator was 6 feet 4 inches high and 3 feet in diameter, and held a ton of water; and the time taken from first running the sea water in to the time of its delivery to the hot well was one hour and fifteen minutes, so that this precipitator could turn out in practice twelve tons in twenty-four hours easily. The prepared water has a density of $\frac{1}{32}$nd, and may with safety be evaporated to a density of $\frac{5}{32}$nds, the contained salts not crystallising out until a density of $\frac{6}{32}$nds to $\frac{7}{32}$nds has been reached. In using the precipitator care must be taken not to add quite enough powder to throw down all the calcium and magnesium salts, as any surplus would cause a bulky though loose precipitate in the boiler should any sea water enter. Prof. Doremus, of the College of the City of New York, proposes to use sodic fluoride as a precipitant, the advantage being that a smaller weight is required; that the action is more rapid and complete; that the sediment shows no tendency to adhere to the sides of a hot vessel, and that the precipitate is less bulky than that following the use of soda ash. Its disadvantage is its greater cost, but this is now to be so far reduced as to make it commercially available.

BELLEVILLE BOILERS AND THEIR APPLICABILITY TO OCEAN-GOING VESSELS.

[Abstract from "Journal of the Royal United Service Institution," Jan., 1891.]

In the course of the last ten or twelve years, with the constant increase of steam pressure, it has been observed that the life of marine boilers has become shorter and shorter, especially with pressures in excess of 90 pounds per square inch. The destruction of the boilers has arisen chiefly from leaks in the seams of the furnaces and of the fire boxes. Even with well made boilers it frequently happens that furnaces, fire boxes and tube plates have to be renewed after three years' service. These costly repairs necessitate the idleness of the vessel for a considerable period of time. Accordingly, in 1884, the Messageries Maritimes S. S. Co. determined to try Belleville boilers, and ordered

from the Belleville works boilers for the new vessel the *Ortegal*, then under construction.

The hull and engines were built at La Ciotat, near Marseilles, at the yard and works of the Messageries Maritimes. The boilers were made at St. Denis, near Paris, at the Belleville works.

Length of vessel,	337 feet 10 inches.
Beam,	45 feet 5 inches.
Draught (mean),	20 feet 8 inches.
Displacement (load),	5,850 tons.

ENGINES AND BOILERS.

Diameter of H.P. cylinder,	$36\frac{3}{16}$ inches.
Diameter of L.P. cylinder,	$64\frac{5}{16}$ inches.
Stroke,	$43\frac{5}{16}$ inches.
Steam pressure,	90 pounds.
Number of boilers,	8
Space occupied by boilers fore and aft,	32 feet 8 inches.
Area of grate surface, { original,	243 square feet.
Area of grate surface, { diminished,	181 square feet.
Heating surface,	6,943 square feet.

The trials of the engines and boilers of the vessel were carried out in April, 1885, and the runs on the measured mile gave the following results:

Number of revolutions per minute,	81.9
Speed in knots,	13.38
I.H.P.	2,110.5
Mean draught,	14 feet 2 inches.
Area of immersed midship section,	521.32 square feet.

Service on board the steamer.—The first trip was from Marseilles to London and back, from the 8th to 29th of May, 1885. In the course of this trip the vessel was under steam 396 hours and the total run was 4,146 miles.

When the vessel started, both from Marseilles and from London, the boilers were filled with fresh water, and during the trip the inevitable loss of water in the boilers was made good by taking in sea water. The blowing off of the boilers was carried on uninterruptedly, and although the saltness of the water did not exceed 6 degrees (with the salinometers used in France 0 degrees corresponds to the density of distilled water, and 10 degrees to the density of water completely impregnated with salt), saline deposits occurred on the lower surfaces of the four lower

rows of tubes. On the run from Marseilles to London twenty tubes were burnt. On inspection in London saline deposits five-sixteenths of an inch thick were discovered on the lower surfaces of the tubes. On the return journey to Marseilles these experiences were repeated, and again twenty tubes were burnt.

This experiment of making good the loss of water in the boilers by filling up with sea water, even on an uninterrupted run of only 2,000 miles, appeared to be thoroughly unsatisfactory, a conclusion to which M. Belleville was compelled to acquiesce; for during the above trips an engineer from M. Belleville's works was on board, and it was therefore impossible to ascribe the unsatisfactory results to the carelessness of the engineers of the *Ortegal*. The *Ortegal* never made a trip from France to South America and back trying her boilers exclusively with sea water, as M. Dubois stated before the Naval Technical Committee.

Repairs and alterations to the boilers after the above second trip.—From the 8th of June to the 11th July, 1885—that is, after the vessel had made 4,116 miles, feeding her boilers with salt water—the following alterations were carried out:

a. The two lower rows of tubes in all the boilers were changed, but the original thickness of the tubes (5 mm.) was adhered to.

b. The water levels were reduced by 14 cm., and the direction into the purifying reservoirs for the steam and for the feed water was changed. The smoke-pipe was furthermore divided into four parts by means of a cross-shaped partition. Each part served to carry off the products of combustion of two boilers. At the same time measures were taken to diminish the loss of fresh water, and to insure the supply of the boilers with distilled water.

Service of the vessel from 11th July, 1885, to 14th February 1889.—With boilers fed exclusively with fresh (distilled) water the *Ortegal* made two trips from Marseilles to London and back, one trip from Marseilles to Bordeaux, and ten trips from Bordeaux to the coasts of La Plata and back.

In the course of these trips the steamer ran 112,807 miles, and was under steam 13,020 hours or 542½ days.

Repairs to boilers and their appliances.—From 7th October to 1st November, 1885, the 100 patent furnace bars were repaired. The doors closing the space in which the boiler tubes are situated were lagged with with asbestos and wood. The back bridges of the boilers were repaired; 33 kilogrammes of zinc were placed in each boiler. This zinc is placed in the collectors of

the feed water, and in the reservoirs for purifying the steam and the feed water.

From 18th March to 11th June, 1886, all the sections were taken out of the boilers; 520 rings at the junctions of the tubes with the boxes and 128 tubes were cut out. The two lower rows of tubes in all the boilers were replaced by thicker ones, viz., with 10 mm. tubes in place of 5 mm. tubes. This alteration was made at M. Belleville's instigation, but was not called for by the unserviceableness of the tubes. The outer casings of the boilers and smoke boxes were repaired, as they had become bent. The former, moreover, appeared weak and had to be strengthened with additional angle irons. The area of the grate surface was diminished from 243 square feet to 180.9 square feet in order to make the combustion more effective, and thus to increase the efficiency of the circulation of the water. An area of 180.9 square feet corresponds to 1,160 I.H.P., by developing which the steamer makes its long runs with a mean speed of 10½ knots. The cross-bars of the grates and the ash-pits were repaired.

Cleaning the boilers and inspection of the boiler appliances after thirty days' steaming.—From 18th March to 22d April, 1889, the steamer for the most part was lying in the ports of South America, as the passage between ports occupied only seven days, and only six boilers were employed. During the thirty-four days of the vessel's stay off the South American coast, the cleaning of the eight boilers was gradually carried out, and a portion only of the boiler appliances were overhauled, as on account of the limited number of engine-room hands, it was impossible to inspect all appliances. In each of the boilers the separator and the four lower rows of tubes were cleaned and all deposit removed. The five upper rows of tubes are cleaned with scrapers only once a year, *i. e.*, after 180 or 200 days' steaming. The deposit is usually from 1 to 3 mm. thick. The thicker deposit was found on the two lower rows of tubes, and principally in the central sections of the boilers. When three stokers were employed for nine hours a day, three days were required for cleaning, washing out, putting together again, and testing the boilers with hydraulic pressure, with the view of seeing that the ends of the tubes were satisfactorily set up. In cleaning the boilers it was clearly apparent in all that the tubes of the lower rows were bent, and that this was especially the case with the central sections. This bending constantly increases with the period of service of the boilers. In one of the boilers the bending of two of the tubes was considerable, and accordingly they were replaced by spare ones. In removing these tubes their washers

and rings had to be cut out. After they had been taken out the amount of their curvature was measured, and in one case it was found to be 1 inch, in the other $\frac{5}{8}$ inch. In all the boilers the above curvature of the tubes is found to be in one and the same direction; that is to say, the convex surface of the tube is always downwards towards the grates. All the zinc plates were renewed, and this takes place approximately after every twenty-five to thirty days' steaming.

The automatic water-gauge cock of the separator, during the trip from Bordeaux to Buenos Ayres, allowed the water to rise 5 inches beyond the middle of the water gauge. On taking the apparatus apart it was found that the float was partially filled with water, in consequence of the passage of steam into the junction of the float with the upright stem, which latter is screwed into the float. After the water had been removed from the float and the upright stem firmly fixed by means of a new washer placed under the shoulder of the stem, the automatic water-gauge cock was put together, and it acted without further failure in the subsequent runs.

The automatic feed apparatus was not inspected, it having worked accurately during the run from Bordeaux to South America. As a general rule, on board the steamer, it was laid down that the tubes of the condenser were to be looked to as frequently as possible, with the view to averting the possibility of any leakage. An inspection of the tubes is, moreover, compulsory on the arrival of the steamer in South America, and on her return to Bordeaux, *i. e.*, approximately after every thirty days' steaming.

On weighing anchor at Las Palmas, in the Canary Islands, a leak of water and steam into the furnace of the port forward boiler was observed; accordingly this boiler was disconnected from the others, and steam was lowered in it. On the next day, in order to fix the position of the leak, this boiler was filled with water, when the leak was found to be from the fourth section (reckoning from forward), so that this section was removed from the boiler. On inspection it was found that the uppermost tube had on its lower surface a hole $6\frac{1}{4}$ inches long and $\frac{1}{8}$ inch wide, and it was determined to replace this tube with a spare one. In order to remove the tube from the section, both the ring of this tube and the tube itself were cut off near the after uniting box, the short portion of the tube which remained screwed into the plate was then cut off, and so, having flattened the portion of the tube which was cut off, it was screwed out of the box.

After the worn out tube had been replaced by a spare one steam

was got up in this boiler and it continued to work successfully with the others. Two working days were required for shifting the worn out tube.

According to the statements of the commander and chief engineer of the vessel, who had served on her since she began her career, this eating away of the tube now occurred for the first time, that is at the commencement of the fifth year of the vessel's service.

On a careful examination of the tube which had been eaten away, it was found that this action had already commenced in another place in this tube, also on the lower portion of its interior surface, and in a short time a hole similar to that already discovered would have been formed.

In spite of feeding of the boilers with distilled water, and of the great care taken of the condensers, the saturation of the water reached 3 degrees, and recourse had to be had to the surface blows a short time to maintain the saturation at 2 to 3 degrees. The bottom blows were used twice every twenty-four hours. At each blow-off the cock was rapidly opened and closed twice, and this was quite sufficient for the removal of the sediment which had accumulated in the lower part of the ejector. Efforts were made to keep the boiler pressure at 120 pounds, which was effected when Cardiff coal was used. With other kinds of coal the pressure varied from 75 to 100 pounds per square inch. When the tubes were being cleaned by steam and also when the fires were being cleaned, the steam pressure, with bad coal, fell to 52 pounds. The quantity of water required for making good the waste of water in the boilers varied from 2 to 3 tons per twenty-four hours. An expenditure of 4 tons was required towards the end of the voyage due to increased loss by leakage through the stuffing boxes.

Expenditure of coal.—Three different kinds of coal were used or tried, viz: 1. Cardiff of the ordinary quality found in the trade. 2. Coal sold as Cardiff, and similar to it in appearance, but actually, as was found on burning it, something between Cardiff and Newcastle. 3. Cheap *briquettes* (15 francs a ton), which were obtained at Dunkirk. In order to attain the ordinary twenty-four hours' run of 250 miles, the engines must make about sixty-eight revolutions and develop about 1,160 I.H.P., and under these conditions, using seven boilers, the area of grate surface of which was 158 square feet, the mean daily expenditure of coal was:

a. For Cardiff of ordinary quality, 34.4 tons, which makes 2.7

pounds per I.H.P. per hour, and gives a consumption of 19.8 pounds per hour per square foot of grate surface.

b. For coal sold as Cardiff, 37.4 tons, or 2.98 pounds per I.H.P. per hour, and 22 pounds per square foot of grate per hour.

c. For the cheap *briquettes*, 41.3 tons, or 3.3 pounds per I.H.P. per hour, and 24.4 pounds per square foot of grate surface.

Experience showed that Belleville's patent iron corrugated grates are not practical, because of their frequent warping and bending, and accordingly they have been replaced by the ordinary cast-iron bars, of which a considerable reserve is always kept on board.

The Belleville boilers, while not working, are kept filled with water, and in order to lower the water to the working level or to empty the boilers, there are valves on the forward ends of the blowing off pipes, which are situated in the hold. The water is passed into the hold through these pipes.

On the *Ortegal* there are spare sections for two boilers, and spare boiler appliances as well. In addition to this there are several spare boiler tubes with their uniting boxes. Generally there is a reserve supply of 25 per cent. of all boiler fittings, not excluding the movable parts of the Belleville donkeys.

Although it is possible to get up steam in half an hour, more time was always allowed and steam was ordinarily got up in two hours.

Although M. Belleville proposes to blow off his boilers immediately the fire has been raked out of the furnaces, and to refill them immediately with water, this practice was never followed on board the *Ortegal*, and usually, in changing the water in the boilers, it was allowed to cool and then passed into the hold.

The engineers of the *Ortegal* find that when steam is got up rapidly, or when the water is rapidly renewed in the boilers, the bending of the tubes, which occurs at all times, is much more considerable, and a leak would probably occur in the joints of the tubes.

On return of the vessel to Bordeaux the interior surfaces of the tubes of the starboard forward boiler were tested by sounding, and it was found that there were fifteen tubes in the walls of which erosion had commenced. In the four lower rows of tubes, however, no erosion of the walls was discovered.

As the boiler was selected at haphazard, and as all the boilers had been subjected to the same conditions during this four years' service, we may suppose that in all the boilers there was similar erosion of the tubes.

NOTES ON THE SERVICE OF THE BOILERS OF THE S. S. *SINDH* OF THE MESSAGERIES MARITIMES.

The following details regarding the service of the *Sindh's* Belleville boilers are from the chief engineer of the vessel:

1. There are twelve boilers on the vessel. The engines are compound, and the steam comes into the engines at a pressure of 90 pounds.

2. The boilers have entered their third year of service, reckoning from the day when steam was first got up. During the two years' service of the boilers they were under steam 400 days.

3. The steamer makes voyages with an average speed of 13½ knots. To attain this speed the engines should develop 1,800 to 2,000 I.H.P., with a daily expenditure of coal (Cardiff) of from 50 to 55 tons. The steamer generally runs with eleven boilers.

4. The boilers are always fed with fresh water, furnished by a boiler and condensing apparatus. The quantity of fresh water to make up the twenty-four hours' waste in the boilers is not more than 5 tons. On the *Sindh*, as on the *Ortegal*, not a drop of water is lost either in blowing off steam or in the exhaust from the auxiliary engines.

5. The boilers are cleared of sediment after twenty-six days of steaming, and then the thickness of the deposit does not exceed 2 mm.

6. During runs of thirteen days the saturation of the water in the boilers is not permitted to exceed 2 degress (2½/32), which is easily maintained by moderate blowing off.

7. The patent Belleville grates, as they get damaged, are replaced by ordinary cast-iron grates.

8. In all the boilers there are many tubes bent in the lower rows, especially in the third row, reckoning from below. The amount of curvature varies from 2 mm. to 28 mm. During two years' service twelve tubes in the lower rows were changed owing to their becoming excessively bent; some of the uniting boxes also had to be changed, as the threads were destroyed when the tubes were screwed out.

9. During the two years' service there was no instance of a hole being formed in any of the tubes, but when tested by sounding it was found that erosion had commenced in several of the tubes of the upper rows in all the boilers. The smoke boxes and iron casings of all the boilers were bent, as was the case on the *Ortegal*. The tube and furnace doors are bent, and do not close tightly. The brick bridges work satisfactorily.

10. There were instances of choking up in right-angled bends of the tubes which served as a communication from the columns

of the water-gauge apparatus with one of the tubes of the second row in each boiler, with the result that the water-gauge glass showed a false level while there was no water in the boiler, and the tubes became red hot.

11. The automatic apparatus acts satisfactorily in every condition of the sea.

In the Belleville boilers of the French cruiser *Milan*, the lower rows of tubes were formerly 6 mm. thick, but many of them bending to the extent of 26 mm., they were exchanged for tubes 10 mm. in thickness; in these new tubes the bends are as yet insignificant. After three years' service of the boilers, holes were found in fifty tubes in the upper rows, and erosion was observed in 200 tubes. Accordingly, a year ago, these 250 tubes were replaced by new ones.

The boilers of the S. S. *L'Australien*, the third vessel of the Messageries Maritimes S.S. Co. fitted with Belleville boilers, are twenty in number, and supply steam to triple-expansion engines of 7,000 I.H.P., giving the ship a speed of 18 knots. The ship was built at the company's works at La Ciotat, and has a displacement of 8,400 tons. The limit of pressure of steam in the boilers is 240 pounds, and the steam is admitted to the engines at a pressure of 180 pounds, while on the foregoing vessels the limit of pressure is 180 pounds, and the steam reaches the engines at a pressure of 90 pounds. The diameter of the tubes is 125 mm. instead of 100 mm. The thickness of the nine upper rows of tubes is 6 mm. in place of 5 mm. The two lower rows of tubes, however, are 10 mm. thick, as on the *Ortegal* and *Sindh*.

The external iron casings of the boilers and the smoke boxes are so made as to expand, and not bend as on the *Ortegal* and *Sindh*. The doors of the tube chambers are in four parts, instead of two as on board the *Ortegal*, where the doors warp and do not shut closely. These doors are of three sheets of iron, the first or inner sheet being of corrugated iron, the other two being flat plates. The spaces between the above sheets are filled, the first with asbestos and the second with cork. In addition to this, parallel to the last sheet and at 15 mm. from it, there is a sheet of gun metal which serves to reflect the heat. There is asbestos packing in the grooves of the frames of the doors, to enable them to be closed tightly. The furnace doors on the *Ortegal* are of three parallel sheets, of which the first or innermost is of cast iron, and the other two of wrought iron; nevertheless the inner sheet often burns and the doors warp. To avoid these defects on board the *Australien*, the inner plate is

made of corrugated cast iron, and is fastened to the iron plates by means of a single bolt, so that the inner plate can be readily replaced in case it is burnt. The ash-pits can be easily taken out and the portion of the bottom plating under them frequently cleaned and painted.

TABLE SHOWING THE PRINCIPAL DETAILS OF THE BELLEVILLE BOILERS ON THE MESSAGERIES MARITIMES STEAMERS.

	Ortegal.	*Sindh.*	*Australien.*
Number of boilers	8	12	20
Grate surface	243 sq. ft.	295 sq. ft.	596 sq. ft.
Heating surface	7,414 sq. ft.	11,050 sq. ft.	23,059 sq. ft.
Ratio of heating to grate surface	30.50	37.46	38.7
Weight of water in boilers (working level)	7.4 tons.	9.6 tons.	20 tons.
Weight of boilers and appliances	130 tons.	190 tons.	280 tons.
Number of H.P.	2,100	2,400	7,000

From this table is found:

a. The grate surface varies from .095 to .12 square feet per I.H.P.

b. The area of the grate in one boiler does not exceed 30 square feet.

c. The weight of the boilers with water and appliances varies from .043 to .083 tons per I.H.P.

Upon this basis the writer attempts to determine the question whether there is any gain in the space occupied by the boilers, and in their weight, over the ordinary double-ended Scotch boilers supplying engines of 12,250 I.H.P. with natural draught. He discusses several different arrangements, and finally arrives at the following conclusions:

1. That, with the arrangement of Belleville boilers which we should most wish for, and with boilers of increased dimensions, not only will there be no saving of space along the length of the ship, but, on the contrary, the machinery space will have to be lengthened by 8 feet to provide for the appliances which are peculiar only to Belleville boilers. The increase of contents of the fore and aft coal bunkers, due to increase of their width, will augment the coal supply only 6 per cent.

2. Arranging the boilers with furnaces towards the transverse water-tight bulkheads, the space occupied by the boilers will be decreased by 10 feet along the length of the vessel; but this 10 feet will be taken up by the apparatus which is peculiar only to the Belleville system. Finally, the space occupied by the Belle-

ville boilers will not be in any case less than the space occupied by the ordinary boilers. This conclusion is borne out by the project which has been put forward for Belleville boilers for the iron-clad *George the Victorious*, now building at Sebastopol, where the Belleville boilers with their appliances occupied 4 feet more space along the length of the vessel than the ordinary boilers, viz: 108 feet, instead of 104 feet, or 4 per cent. more, and that too with a grate surface per I.H.P. of only .096 square feet.

The further arrangement of Belleville boilers, viz: furnace to furnace, is not put forward, because such an arrangement, although it would lead to saving of space along the length of the vessel of 4 feet, is quite inadmissible for Belleville boilers, because if they are thus arranged the heat will be unbearable and the stokers will be unable to work. This arrangement may be admissible for ordinary boilers, but it is absolutely inadmissible with the Belleville type, because with the latter the walls and doors heat much more than with the ordinary boilers.

3. The weight of the cylindrical boilers with water and appliances will be 970 tons, or .079 tons per I.H.P. The weight of the Belleville boilers with water and appliances will be 612 tons, reckoning .050 per I.H.P., and so the saving in weight in favor of the Belleville boilers will be 355 tons, or about 36 per cent.

According to the statement of the assistant manager of the workshops of the Messageries Maritimes Company the cost of the Belleville boilers to the company is 10 per cent. more than the cost of ordinary cylindrical boilers of the same I.H.P.

Conclusions.—1. The Belleville boilers with their appliances cannot, in any case, occupy less space fore and aft than the ordinary cylindrical boilers. On the contrary, the Belleville boilers with their appliances, if arranged in the most advantageous manner, will occupy about 6 per cent. more than ordinary boilers along the line of the vessel. The saving of space along the width of the vessel will enable the coal supply to be increased by not more than 10 per cent., and this increased supply will be only apparent, for Belleville boilers expend 10 per cent. more coal than ordinary boilers per I.H.P.

2. The weight of the Belleville boilers with water, appliances and spare parts will be from 36 to 42 per cent. less than the weight of cylindrical boilers for larger vessels.

3. The working and management of these boilers present no difficulties, even with voyages of 30 days' steaming.

4. All the automatic appliances of the Belleville boilers act thoroughly satisfactorily, independently of the condition of the sea.

5. The quantity of distilled water required to make good the waste does not exceed 3 tons in twenty-four hours for each thousand I.H.P. The Belleville boiler should not be fed with sea water except in case of the most urgent necessity. If fed with distilled water it does not require to be cleaned until after 30 days' steaming; but if fed with salt water, the tubes will inevitably burn through, even after 8 days' steaming, as is conclusively shown by the trips of the steamer *Ortegal* from Marseilles to London and back.

6. In the Belleville type of boiler, while steam is being got up, or combustion is slow, there is a rapid formation of deposit in the tubes, a fact which M. Belleville himself does not deny, and which forms one of the disadvantages of this type, especially for vessels which are required to get up steam frequently, such as torpedo-boats and steam-launches; and accordingly Belleville boilers cannot be recommended for these vessels. Moreover, for small vessels, the weight of the Belleville boiler is greater than the weight of the ordinary boiler of the same I.H.P.

7. The four years' service of the Belleville boilers on the *Ortegal*, and their two years' service on the *Sindh*, point to the conclusion that when they are fed with fresh water they may serve without repair for the first four years, but after four years' service the tubes must be changed gradually. By the end of the sixth year all the tubes should have been replaced, both on account of the erosion and also on account of the bending of the tubes in the lower rows. This bending took place in the boilers of all the above named vessels, and it was conclusively shown that it was neither due to careless management nor to absence of water in the boilers. Replacing unserviceable tubes by spare ones can be easily carried out, and the boilers, with tubes replaced gradually during the course of five or six years' service, can serve for another four to six years; but at the expiration of ten or twelve years' service the remaining portions of the boilers, viz: separators, the external casings, the smoke boxes, funnels, and other parts will become unserviceable, and new boilers with all their appliances will have to be put in. In the course of ten or twelve years' service the cost of repairs will be about 50 per cent. of the original cost, and when repairs are going on, the deck will not have to be broken up. During the service of this type of boiler the steam pressure carried will not have to be decreased.

8. Taking into consideration the unsatisfactory service of the ordinary Scotch boiler with pressures greater than 90 pounds, as is shown by the experience of the large French steamship companies, where the service of such boilers does not exceed three

to four years, we may conclude that Belleville boilers can successfully replace ordinary cylindrical boilers, commencing with pressures of 90 pounds, for vessels of not less than 2,000 tons displacement. For pressures of less than 90 pounds Belleville boilers cannot be recommended, for with these pressures ordinary boilers serve successfully for from 8 to 10 years, and are cheaper than Belleville boilers, both originally and for purposes of repair.

9. In the construction of Belleville boilers it is necessary to be most exacting as to the quality of the material employed, and also as regards the perfection of manufacture of each detail of the boilers and their appliances, because it is only by the accurate observance of these conditions that the boilers can do their work successfully.

It is the opinion of the Council that a query corner would make a useful feature of the JOURNAL. Any reader wanting information on one point or another, would do well to write to the Secretary. The question would be answered either by the people at the Bureau of Steam Engineering, or submitted to some member who is known to be in a position to give the desired information. Question and answer will be published in the JOURNAL.

SHIPS.

UNITED STATES.

Protected Cruiser No. 13.—This vessel is practically a duplicate of *Cruiser No. 12*, a few unimportant changes having been made as experience was gained from working out the details of that vessel since the contract for her construction was made. The special feature of *Cruiser No. 12*, the triple screws, is preserved, and the principal scantlings are the same. The following are the principal dimensions of hull and machinery for *Cruiser No. 13:* Length on load water line, 412 feet; beam, 58 feet; mean draught on trial, 22 feet 7¾ inches; trial displace-

ment, 7,350 tons; normal coal supply on trial, 750 tons; bunker capacity, 2,000 tons; displacement with full bunkers, 8,600 tons. There will be two pole masts fitted for fore-and-aft sail. The protective deck is 4 inches thick on the slopes and 2½ inches elsewhere.

There will be three triple-expansion engines, each driving a separate screw, and each in a separate water-tight compartment. The cylinders will be 42, 59 and 92 inches in diameter by 42 inches stroke, and it is expected that the I.H.P. of main engines and the engines driving the air and circulating pumps will be about 21,000 when the main engines are making 129 revolutions.

Piston valves will be used for all the cylinders, driven by Stephenson double-bar links; there will be one valve for the H.P., two for the I.P., and four for the L.P. cylinders. The framing will consist of cast-steel inverted columns at the back, and cylindrical forged-steel columns at the front. The bed plates will be of cast steel. The crank shafts will be in three interchangeable and reversible sections. All the shafting will be of hollow forged steel.

The condensers will be cylindrical, of composition and sheet brass. The cooling surface of each condenser will be about 9,474 square feet, or an aggregate of 28,422 square feet. The air pumps will be driven through gearing by vertical, double-cylinder, simple engines, arranged to exhaust into the receivers or condensers as may be desired. The circulating pumps will be centrifugal, two for each condenser, driven by independent engines. There will be two auxiliary condensers, connected to the auxiliary exhaust main and to the steam discharge pipe from the evaporators.

The propellers will be of manganese bronze, two right-handed and one left-handed.

There will be six double-ended boilers about 15 feet 9 inches diameter and 20 feet long, two double-ended boilers about 15 feet 3 inches diameter and 18 feet 1¾ inches long, and two single-ended auxiliary boilers about 10 feet 1¾ inches diameter and 8 feet 6 inches long. The working pressure will be 160 pounds.

The main boilers will be placed in four water-tight compartments, and the two auxiliary boilers will be placed on the protective deck. There will be three athwartship fire rooms in each of the main boiler compartments. The main boilers will have eight furnaces each, those for the larger boilers being 3 feet 4 inches internal diameter, and for the smaller 3 feet 3 inches internal diameter. The auxiliary boilers will each have two furnaces, 2 feet 9 inches internal diameter. The total heating surface of the main and auxiliary boilers will be about 49,250 square feet, and the grate surface 1,522 square feet. There will be two smoke pipes.

The usual feed pumps, blowers, and other auxiliary machinery will be furnished.

Torpedo Boat No. 2.—Although the bids for this boat were opened some time since, no decision has yet been made by the Department. Meanwhile the Department is preparing designs of its own for a boat somewhat larger than that called for originally. The following comparison of the dimensions of the Department boat with those submitted by the bidders may be interesting.

(All the boats are to have twin screws.)

	Department.	Cowles.	Herreshoff.
Length on L.W.L	150′	144′0″	156′0″
Beam	16′3″	15′10″	15′7″
Mean draught	4′9″	4′4″	5′5″
Displacement, tons	125	112	134
Immersed midship section, square feet	56.72	72.2	55
Estimated I.H.P	1,800	2,170	2,400
H.P. cylinder, diameter	11½″	13″	14″
1st intermediate cylinder, diameter	16″	20″	20″
2d intermediate cylinder, diameter	21½″	—	28″
L.P. cylinder, diameter	29″	31.5″	2 of 28″
Stroke	18″	15″	16.5″
Steam pressure, pounds	250	250	240
Kind of boilers	Tubulous.	Cowles.	Thornycroft.
Grate surface, square feet	90	90	—
Heating surface, square feet	40 to 50:1	4,144	—
Designed speed, knots	24.0	24.1	240

ENGLAND.

Some of the ships provided for by the Naval Defence Act of 1889 have been completed, and many are nearing completion. To facilitate the classification as the launches and trials are reported, the list of new ships appropriated for by that act is given below:

1st class battle ships (8): *Ramillies, Empress of India* (formerly *Renown*), *Repulse, Resolution, Revenge, Royal Oak, Royal Sovereign*, all barbettes; *Hood*, turret ship.

2d class battle ships (2): *Barfleur, Centurion.*

Cruisers, 1st class (9): *Royal Arthur* (formerly *Centaur*), *Crescent, Edgar, Endymion, Gibralter, Grafton, Hawke, St. George, Theseus.*

Cruisers, 2d class (29): *Andromache, Aeolus, Apollo, Astraea, Bonaventure, Brilliant, Cambrian, Charybdis, Flora, Forte, Fox, Hermione, Indefatigable, Intrepid, Iphigenia, Latona, Melampus, Naiad, Pique, Rainbow, Retribution, Sappho, Scylla, Sirius, Spartan, Sybille, Terpsichore, Thetis, Tribune.*

Torpedo gunboats (17): *Alarm, Dryad, Hazard, Jason, Niger, Speedy, Antelope, Halcyon, Hebe, Jaseur, Onyx, Circe, Harriet, Hussar, Leda, Renard, Assaye.*

Royal Sovereign.—This ship, the first of eight similar ships provided by the "Naval Defence Act" and the largest battle ship yet constructed for the British Navy, was recently launched from the Portsmouth Dock Yard.

The principal dimensions are as follows: Length, 380 feet; breadth, 75 feet; draught, mean, 27.5 feet; displacement at this draught, 14,150 tons: I.H.P., natural draft, 9,000; I.H.P., forced draft, 13,000; speed, natural draft, 16 knots; forced draft, 17.5 knots.

Coal at load draught of 27.5 feet, 900 tons; estimated coal endurance at 10 knots, 5,000 miles.

The motive machinery, which is being built by Humphreys, Tennant & Co., is of the inverted vertical triple-expansion type. Cylinder diameters: H.P., 40 inches; I.P., 59 inches; L.P., 88 inches, with a common stroke of 51 inches; revolutions at full power, 108. The cylinders are all jacketed, the drains leading

to the auxiliary condenser. Pressures of 100 and of 50 pounds are used in the I.P. and L.P. jackets respectively, and steam of boiler pressure, 150 pounds, in the jacket of the H.P. cylinder. The H.P. cylinder liner is of forged steel, those for the I.P. and L.P. cylinders being of cast iron. The steel pistons are fitted with wide single packing rings, of phosphor bronze for the H.P. and of cast iron for the I.P. and L.P. cylinders. Length of connecting rods, 8 feet 4 inches. The shafting is of steel and hollow. Diameter of crank shaft, 15¾ inches; crank pins, 16¼ diameter by 18 inches long; diameter of line shafting, 14¾ inches; of shaft in stern bearing, exclusive of casing, 15¾ inches; of shaft outside of ship, 16 inches; diameter of hole, about 8 inches; thrust surface, 1,500 square inches; brass bushings in stern and hanger bearings 1¼ inches thick; shaft casing, 1⅛ inches at bearings; diameter of propeller, 17½ feet; condensing surface of main condensers (brass), 14,000 square feet; of both auxiliary condensers (one in each engine room), 1,800 square feet. The condenser tubes are of brass, untinned: copper, 70; tin, 1; remainder zinc. There are two separate circulating pumping engines in each engine room, capable of discharging, with 100 pounds of steam and no vacuum, at 300 revolutions, 1,100 tons of water from the bilge per hour. There are two feed pumps in each boiler compartment, and four steam pumps in each engine room. There are three dynamos and engines generating a current of 400 amperes and 80 volts. There are two sets of evaporators and distillers, the evaporators capable of making 400 gallons per hour, the distillers of 200 gallons of pure ærated water per hour.

There are eight boilers with 32 furnaces. The tube heating surface is 17,000 square feet; grate surface, 700; estimated total weight of machinery, including water and spare parts, 1,100 tons.

Armament, four 67-ton B. L.; ten 6-inch Q. F.; twenty-four 6-pounder and 3-pounder Q. F.; weight of armament, 4,100 tons; height of guns above designed water line, 23 feet; length of armor belt, 250 feet; greatest thickness side armor, 18 inches; protective deck, 3 inches; weight of horizontal armor and glacis plates, 1,100 tons; of armor and backing and protective deck, 4,550 tons.

Royal Arthur.—First class protected cruiser, is an example of the rapid work possible in a dock yard under proper inducements. The first keel plate was laid down at the Royal Dock Yard, Portsmouth, Jan. 20, 1890, and in thirteen months thereafter she was ready for launching.

The following are the chief features of the *Royal Arthur* as designed: Length, 360 feet; breadth, 60 feet 8 inches; mean load draught, 23 feet 9 inches; displacement, 7,700 tons; weight of hull and fittings, 4,040 tons; I.H.P. forced draft, 12,000; I.H.P. natural draft, 7,500; maximum speed on measured mile, 20 knots; speed on measured mile, natural draft, 18 knots; coal at load draft, 850 tons; radius of action at 10 knots, 10,000 miles; maximum thickness of protective deck, 5 inches.

Original armament two 9.2-inch guns, ten 6-inch, and twelve 6-pounders, besides machine guns and torpedoes. One of the 9.2-inch guns was, however, replaced by two 6-inch quick-firing guns, mounted as bow chasers, the forecastle being built up $7\frac{1}{2}$ feet higher, running aft 110 feet, placing these guns $25\frac{1}{2}$ feet above water.

The engines are inverted vertical triple-expansion. Cylinders are steam-jacketed. H.P. cylinders have piston valves, the I. P. and L. P. slides, all worked by link motion. The engine frames will be four cast-steel standards for each cylinder. Cylinder diameters are 40, 59 and 88 by 51 inches stroke. Steam pressure 150 pounds. The maximum I.H.P. of 12,000 is to be maintained for four hours at sea with one inch of air pressure. With one-half inch of air pressure 10,000 I.H.P. are to be developed for eight hours at sea. Diameter of propellers $16\frac{1}{2}$ feet; revolutions at full power, 100. Length of connecting rods, 8 feet. Aggregate length of bearing for each engine, about 9 feet. The shaft diameters are as for the *Royal Sovereign*, the hole being $8\frac{1}{2}$ inches; thrust surface, 1,300 square inches; diameter of piston rods, 8 inches; of connecting rods, $7\frac{3}{8}$ in the middle and $6\frac{1}{8}$ at the ends. Total cooling surface 13,500 square feet. Condenser tubes $\frac{3}{4}$ inch diameter, spaced $1\frac{1}{8}$ inches apart. Cooling surface of auxiliary condenser (one in each engine room) 1,600 square feet. Main air pumps 33 inches diameter by 22 inches stroke, worked from H.P.

cross-head. Auxiliary air pumps 9 inches diameter by 7 inches stroke. There will be eight fans and engines for forcing the draft, 5 feet 6 inches in diameter, making about 350 turns. There will be eight single-ended boilers, 16 feet 3 inches diameter by 9 feet 10 inches long; boiler pressure, 155 pounds. There will not be less than two combustion chambers in each boiler. There are 32 furnaces, 43 inches diameter by 7 feet 6 inches long. Grate area, 855 square feet; tube heating surface 21,400 square feet. The tubes will be $2\frac{1}{2}$ inches diameter, ordinary tubes weighing 4 pounds per foot, stay tubes weighing 6 pounds per foot. They are tested to 600 pounds. The shell plates of the boilers will be $1\frac{3}{16}$ inches thick; tube plates, $\frac{13}{16}$; lower backs, $\frac{3}{4}$; other parts of ends $\frac{7}{8}$; the furnaces $\frac{9}{16}$ and all other internal parts $\frac{1}{2}$. Total weight of machinery, with water and spare parts, 1,180 tons: main engines and shafting in engine rooms and spare gear, 400 tons; boilers and fittings and water, 670 tons; screws, stern tubes and shafting to engine rooms, 86.

Tribune.—Second class cruiser, was launched on the 24th of February last from the shipbuilding yards of Messrs. J. G. Thomson, Clydebank, the other two of this class, the *Terpsichore* and *Thetis*, having been launched from the same yard in October and December respectively.

The principal dimensions of the *Tribune* are as follows:

Length,	300.75 feet.
Breadth,	43 feet.
Depth to upper deck,	22.75 feet.
Mean draught,	16.5 feet.
Displacement at this draught,	3,400 tons.

The estimated speed is 20 knots per hour, on an estimated I.H.P. of 9,000.

The propelling machinery will consist of two sets of inverted vertical triple-expansion engines, supplied with steam from five cylindrical steel boilers, designed for a working pressure of 155 pounds per square inch above the atmosphere.

The two propellers are made of naval brass. The normal coal supply will be 400 tons at the load draft, giving the vessel

an estimated endurance of 8,000 miles at a speed of 10 knots an hour.

The vulnerable parts of the ship are to be protected by a steel protective deck over the whole length of the vessel, and extending to four feet below the water-line at the sides. The thickness of this protective deck at the sides is to be two inches, and on the flat portions one inch.

The armament of the *Tribune* will consist of two 6-inch quick-firing guns, one of them being mounted on the forecastle and the other one on the poop. In addition there will be six 4.7-inch quick-firing 36-pounders, three on each broadside.

The auxiliary armament will consist of eight quick-firing 6-pounder Hotchkiss guns, one 3-pounder Hotchkiss, and four 5-barreled Nordenfeldt guns.

The ship is fitted with four torpedo tubes.

There are no less than eighty water-tight compartments in the ship.

Indefatigable.—March 6, 1891, the second-class protected cruiser *Indefatigable* was launched from the yard of the London and Glasgow Engineering and Iron Shipbuilding Co., at Govan. This vessel is the first of the three second-class protected cruisers now in process of construction for the British naval authorities, the others of the class being the *Intrepid* and *Iphigenia.* The hull is constructed of steel, but the ship being intended for foreign service, the wetted surface, from the keel to about three feet above the load water line, is sheathed with teak and coppered, and as a consequence the stern post, stem, ram, rudder post, rudder, propeller and shaft-tube brackets are of phosphor bronze. The twin screws are of gun metal.

The dimensions of the vessel are as follows:

Length,	300 feet.
Breadth over teak sheathing,	43.66 feet.
Depth, moulded,	22.75 feet.
Displacement,	3,600 tons.

There are two sets of triple-expansion surface-condensing inverted vertical engines with cylinders of 33.5 inches, 49 inches and 74 inches in diameter, with a common stroke of 39 inches.

The I.H.P. which it is estimated these engines will develop is 9,000.

The boilers are like those of the *Tribune*.

The engine rooms, which are separated by a fore-and-aft steel bulkhead extending to the upper deck, are roomy and well ventilated.

The armament is similar to that of the *Tribune*, there being one 9-pounder field gun in addition.

Latona.—The second class cruiser *Latona*, whose machinery was constructed by the Barrow Naval Construction and Armaments Company, has made a successful eight-hours' natural-draft trial with the following results:

The I.H.P. developed was 7,247, the engines making 136 revolutions per minute, boiler pressure 153 pounds, vacuum 28 and 27.25 inches. A mean air pressure of .44 inches of water was maintained in the fire-room. A mean speed of 19.05 knots per hour was made on the measured mile. The forced draft trial took place later, with the following results:

Air pressure in fire-room, 1¼ inches of water; boiler pressure, 152 pounds; vacuum, 26.5; revolutions, 145. I.H.P. of the starboard engine, 4,643, and of the port engine, 4,795, a collective I.H.P. of 9,438, the contract being for 9,000. A speed of about 20 knots was realized as a mean of four runs over the measured mile.

A first attempt to make the forced-draft trial proved unsuccessful, due to the pressure exerted by the bow wave forcing out the plugs of the hawse holes and flooding the forward compartments of the ship. On the successful trip the trim was altered only to the extent of decreasing the immersion forward 6 inches (the ship being down to her load draught), yet this small change was sufficient almost to abolish the bow wave.

The success of the *Latona* on her forced-draft trial is attributed not only to the boilers (3 double-ended) being increased in size relatively to the power to be developed by the engines, but in a great measure to the fact that each furnace was provided with an independent combustion chamber. This type of boiler is in consequence to be adopted in all the vessels built under the

Naval Defence Act, whereby it will be possible not only to steam them at their maximum power, but without fear of the recurrence of such an accident as that on board the *Barracouta*.

While on this subject of independent combustion chambers, some comments from *Industries* of February 27, 1891, may be of interest. Forced draft was introduced into the Royal Navy so as to get a large horse-power from a small weight of boilers by increasing the quantity of coal burnt per square foot of grate. However, the ratio of heating to grate surface remained about as it was for natural draft. One alteration in design, however, was carried out with the same idea in view of saving weight, viz: the use of double-ended boilers with a back connection common to all the furnaces. This construction was used on the *Galatea* and the *Undaunted* and worked successfully, there being about 18.5 I.H.P. developed per square foot of grate. This success led to the extensive use of this type of boiler, and it was expected by increasing the air pressure to get as much as 20 I.H.P. per square foot of grate. Then came a series of failures and accidents, the fatal one on the *Barracouta* among them. It was thought that the use of one common combustion chamber had something to do with these failures, and so on some ships, the *Katoomba*, sister ship of the *Pallas* among them, the combustion chamber was divided into separate compartments by brick work. In spite of the brick work, however, an accident occurred on the *Katoomba* similar to that on the *Barracouta*, flames issuing from the furnace mouths; the tubes showed signs of leaking, but whether the leaks caused the back draft, or *vice versa*, is not known. However, when it comes to subdividing a common combustion chamber by brick work, there can be no doubt but that the arrangement of a separate chamber to each furnace is the better. The gain in weight is gone, as the brick work weighs nearly as much as the steel sides, without adding heating surface. Of course the weight of the double back is saved, but at the same time a very efficient area of heating surface is sacrificed. Theoretically we should expect the *Pallas* (see below) to do better than the *Katoomba*, and practically this is confirmed, for what the *Pallas* did with .1 inch of air pressure, it was necessary to use .75 for in the *Katoomba*.

This means that more heat was generated in the furnaces of the latter, but instead of passing into the water the excess simply went up the funnel. Taking all things together, it is probable that we have seen the last of the combustion chamber common to all the furnaces.

Pallas.—One of six second-class cruisers which were built for one of the Australian governments. The others are the *Katoomba*, *Mildura*, *Wallaroo*, *Tauranga* and *Ringarooma* (changed from *Pandora*, *Pelorus*, *Persian*, *Phœnix* and *Psyche*). The *Pearl*, *Philomel* and *Phœbe* also are vessels of the same class. She was commenced July 1, 1889, and was completed in twelve months. Displacement, 2,573; length, 260 feet; breadth, 41 feet; mean load draught, 15 feet 6 inches; I.H.P. under forced draft, 7,500; expected speed, 19 knots. At natural draft and 4,500 I.H.P. the estimated speed is 16½ knots. Bunker capacity, 300 tons. She will carry eight 4.7-inch and eight 3-pounder quick-firing guns, and a number of machine guns and torpedoes.

Continuous sea-going speed on a four days' run is to be 14¾ knots at 2,500 I.H.P.

On the natural draft trial of eight hours the engines indicated 5,055 horses, and a speed of 17½ knots was realized. On the four hours' trial under forced draft, with 1½ inches of air pressure, the I.H.P. was 3,690 and 3,627 of the starboard and port engines respectively, a total of 7,317, the contract requirement being for 7,500. There was a falling off during the last half hour, due to a heated bearing. The vacuum was 27 and 28 inches. The speed obtained was 19 knots. The *Pallas* is the last of the secondary cruisers in which trouble was anticipated in working under forced draft. Her boilers, though fitted with independent combustion chambers, are less by 25 per cent. in power than those with which similar vessels now under contract are provided.

Pearl.—The forced-draft trial of the cruiser *Pearl* took place with results satisfactory to the admiralty and to the contractors. The boiler pressure of 145 pounds per square inch was maintained throughout the test under an air pressure in the closed fire-rooms of 1.5 inches of water. The vacuum maintained was

25 inches, and the revolutions of engines showed a mean of 157.3 for the starboard screw, and 158.5 for the port. The mean pressures were as follows: H.P. cylinders 52.9 and 56.4, starboard and port respectively; I.P. cylinders 31 and 29.6; L.P., 14.2 and 13.1. The I.H.P. developed aggregated 7,175, divided as follows: starboard engines 3,579; port engines 3,587. And a mean speed of 19.8 knots was logged, the contract being for 19 knots. The maximum I.H.P. was reached during the fifth half hour of the trial when 8,016 was indicated.

Assaye.—On the 11th of February last there was launched from the yard of Armstrong, Mitchell & Co., at Elswick, the torpedo gunboat *Assaye*, of 740 tons displacement, intended for the service of the Indian Government.

The principal dimensions of this vessel are as follows:

Length,	230	feet.
Breadth.	27	feet.
Mean draft,	8.25	feet.
Displacement at this draft,	740	tons.
Estimated I.H.P., with forced draught,	4,500	
Speed,	21	knots.

The estimated coal endurance of this vessel, with the normal bunker capacity of 100 tons, is 3,000 knots at 10 knots per hour.

The *Assaye* is of the same class as the *Plassy*, built by the same firm for the Indian Government, and launched in July, 1890.

The armament of the *Assaye* will consist of two 12 cm. rapid-firing guns, four 3-pounder rapid-firing guns, and five torpedo launching tubes.

Hercules.—Battle ship of 8,680 tons (built in 1868), is to receive triple-expansion engines of 8,500 I.H.P.

FRANCE.

Le Hoche.—Preparatory to her departure for the Mediterranean the turreted iron-clad *Le Hoche* underwent, in January, a series

of trials to test her machinery and sea-going qualities. The forced-draft trial lasted two hours; coal consumption was limited to 30.7 pounds per square foot of grate per hour; the I.H.P. obtained was 11,000, the engines making 82 revolutions; speed 16 knots. On a six hours' natural-draft trial the revolutions were 70, the speed 14 knots. The ends of this ship are very low, a feature which was much criticised. However, on a twenty-four hours' trial at sea, two hours under forced draft, the remainder under natural draft, she not only manœuvred well, but behaved well in a seaway, although her ends were constantly swept by the seas.

Le Troude.—Third class cruiser. This ship was constructed at Bordeaux by la Société des Chantiers et Ateliers de la Gironde. She completed her trials on December 18 of last year, and has been accepted by the Government. Two other cruisers of the same class are completed and ready for trial, the *Lalande* and the *Cosmao.*

The principal dimensions of these cruisers, built according to a ministerial program of February 2, 1886, are as follows:

Length on L.W.L.		311.60 feet.
Beam on L.W.L.		31.26 feet.
Depth of hold	Aft	25.62 feet.
	Midships	21.65 feet.
	Forward	23.68 feet.
Draught	Aft	16.96 feet.
	Forward	11.05 feet.
	Mean	14.01 feet.
Displacement		1,845 tons.
Immersed midship section		343.3 square feet.
Displacement per inch of immersion at load draught		16.26 tons.
Sail area (three schooner-rigged masts)		6,563 square feet.

The lines of these cruisers are very fine, especially those of the run. The tumble-home of the top sides and the disposition of the superstructure permit a wide range of train for the guns and torpedo tubes.

The design of the hull is such as to secure a good coefficient of flotation, fair manœuvering qualities and minimum of vibration

of the stern, inevitable in ships of light scantlings when driven at their utmost speed.

The armament consists of four 5.5-inch guns; four 47-mm. rapid-fire guns; four 37-mm. revolving cannon; four torpedo tubes.

By reason of the tumble-home of the sides the two forward and the two after guns can cross their fire, concentrating at a point 328 and 984 feet distant from the bow and stern respectively.

The engines and boilers were constructed by M. Schneider & Co., Creusot.

The engines are horizontal compound, actuating three-bladed manganese bronze propellers 13.38 feet in diameter with a pitch of 16.65 feet. Cylinder diameters are 30.38 and 61.66 inches; stroke, 3 feet. There are five cylindrical straight-away boilers, 19 feet long and of 10.17 feet mean diameter; grate surface, 301.28 square feet; heating surface, 13,450 square feet; steam pressure, 100 pounds.

The closed fire-room system of forced draft is used, five blowers running at 600 revolutions furnishing above 26,475 cubic feet of air per minute at a pressure of 3.1 inches of water. During the trials these blowers were run at only 380 turns, the boiler pressure being easily maintained at 100 pounds.

According to contract the Société des Chantiers et Ateliers de la Gironde had to fulfill the following conditions:

1. During a two hours' forced-draft trial the minimum mean speed obtained was to be 19.5 knots.

2. During a trial of twelve hours a minimum mean speed of 17 knots was to be maintained at a coal expenditure during the first six hours not exceeding 1.98 pounds per hour per I.H.P.

3. Finally, during a six hours' trial with only enough grate surface in use to make about one-fourth of the total power, the coal consumption per I.H.P. per hour was not to exceed 2.2 pounds.

The subjoined table shows the results obtained. On all the trials the boilers, engines and all auxiliary apparatus worked very

well. The vibrations of the hull were very slight at all times, especially when compared with other ships of similar design.

	Forced draft trial, 2 hours, Dec. 1, 1890.	Trial at reduced power, 6 hours, Dec. 9, 1890.	Trial of 12 hours, Dec. 11, 1890.
Draft, mean, in feet	14	13.97	14.04
Displacement, in tons	1,845	1,837.5	1,850.14
Immersed midship section, sq. ft., (B^a)	343.24	342.28	344.32
State of the sea	Smooth.	Smooth.	Smooth.
Force of the wind	4	3	2
Steam pressure, pounds	100	91.6	98
Revolutions, mean	133.4	85.05	108.74
Total I.H.P., not including 16 I.H.P., about, absorbed by the steering and electric lighting engines (F)	6,156	1,568	3,344
Speed in knots (V)	20.913	14.208	17.565
Value of M in the formula $V = M\sqrt[3]{\frac{F}{B^a}}$	3.621	3.855	3.711
Consumption of coal per hour per I.H.P., pounds	2.81	2.12	1.936
Distance in nautical miles vessel can steam with the coal supply of 282 tons.	764 6	2,658.7	1,621

The second-class cruiser *Davout*, launched October 31, 1889, was to have served as a type for a number of similar ships. It was found, however, that an increase of displacement was necessary to accommodate the engines, designed to develop 9,000 I.H.P. The plans of the *Suchet*, already in course of construction, were therefore altered, and the *Chasseloup-Laubat* and the *Bugeaud* were redesigned for a greater displacement. The following is a comparison of these ships:

	Davout.	*Suchet.*	*Bugeaud* and *Chasseloup-Laubat.*
Length between perpendiculars, feet	288.6	311.6	308.3
Beam, extreme, feet	39 7	39.7	43.4
Draught, aft, feet	18.7	19.5	20.8
Displacement, tons	2,972.5	3,367.3	3,655 o
I.H.P.	9,000	9,000	9,000
Speed, naut. miles	20	20	19.5
Weight of machinery, tons	748	.....	762

The protective deck has a thickness of 1.18 inches on the flat and 3.15 inches on the slopes.

Marceau.—First-class armored ship, has satisfactorily passed her trials previous to acceptance by the government. The displacement is 10,420 tons. The speed developed on a four hours' full-power trial was 16.4 knots, the I.H.P. developed being 10,830. The *Marceau* has been building since 1881, and her construction is consequently somewhat antiquated. This applies especially to the protection given her battery, which is such as to render the fighting of the guns difficult in the face of a clever enemy.

The principal armament consists of four 13.39-inch guns in barbette turrets, and of seventeen 5.51-inch guns. The 13.39-inch guns are placed in four turrets, one forward, one aft, and two others at the sides amidships. The arrangement is such that three guns can be concentrated on any point of the horizon. Each gun fired seven charges, of which five were service charges. The port gun firing astern shattered the captain's boat, which was secured for sea. The port gun firing ahead bulged some of the superstructure plates and upset the men's hammock nettings. These injuries were very slight, but they served to show that wood should not be used in the superstructure, which should be well stiffened. It was established that the fighting of the 5.5-inch guns, which are placed below the turret guns, was not interfered with by the latter. To discover the effect of the concussion on the crew, mannikins and four sheep were distributed in various places about the deck. The sheep, while not killed, seemed completely stunned after a few shots, and of the mannikins several about the deck were shattered, while those in the battery remained intact.

M. Normand has recently delivered to the French Government four single-screw *Torpedo Boats, Nos. 126, 127* and *128*, and one twin-screw boat, the *Avant-Garde*. The consumption of fuel at slow speed—ten knots—was found to be so small in the case of *Nos. 126, 127* and the *Avant-Garde*, that it was deemed advisable to carry out a trial with *No. 128* with exceptional care, and for this purpose the boat made two runs on successive days, of

eight hours each. It was found that the consumption of fuel averaged for both days 0.462 kilos. per French horse-power per hour. Every precaution was taken to get the fires into the same condition at the end as at the beginning of the trial, and it does not appear that there was much room for error. However, to be on the safe side, M. Normand elects to put down the consumption at 0.5 kilos. per horse per hour, which means about 1.25 pounds of coal per English horse-power per hour, an extraordinarily low figure, when it is borne in mind that the engines are compound, not triple expansion. The trials were carried out by an official committee. The principal dimensions of the boat are as follows: Length over all, including the rudder, 121 feet; beam, 13 feet 2 inches; mean draught, 3 feet 9½ inches; displacement, about 79 tons.

The boiler is of the locomotive type, but presents many peculiarities. There are 317 tubes, 8 feet 8 inches long and 1½ inches diameter. These tubes are rolled into the plates, and fitted at the fire-box end with bell-mouthed ferrules. The grate surface is a little over 30 square feet. The total heating surface is 1,425 square feet; the pressure 143 pounds per square inch. A deep hanging bridge is worked into the flat crown of the fire-box, and a fire-brick bridge curves back over the grate. Thus a species of combustion chamber is formed, which, with the bell-mouthed ferrules, perfectly protects the tube ends and tube plate, and prevents leakage. These boilers give no trouble whatever. The total weight of the boiler, with water and all fittings and accessories, is nearly 16 tons. Of this the water represents about 4.5 tons, and the grate bars and bearers about 17 cwt. The external fire-box crown is brought down lower than usual, and to provide steam room a steam drum, about 2 feet in diameter, has been added to the barrel of the boiler. In the water space at each side of the fire box thin plates are placed to permit the quiet descent of water between them and the outer shell plate, while the steam and water together can rise unhindered at the fire-box side. The fire box is higher than in previous boats built by M. Normand. The tubes are of brass with copper ends next the fire-box.

The engines are intended to indicate 900 horse power when making 320 revolutions per minute. They weigh complete without water about 12 tons. The water in the condenser and hot well adds about 1.25 tons to this. The water circulates automatically through the condenser when the boat is in motion; a small centrifugal pump is provided to maintain the circulation when the boat is not moving through the water. The cylinders are 17.3 inches and 27.24 inches by 17.3 inches. The valve boxes are placed between the cylinders. They are cast in one with the small cylinder. The cylinders are jacketed all over. The jackets are supplied direct from the valve chest of the high-pressure cylinder, and the drain pipes are fixed at the lowest points so that the jackets can be kept quite clear of water. At each end of the high-pressure cylinder is fixed a small relief valve which opens if the compression becomes excessive, as may be the case when the engines are running linked up. If it were not for these valves the engines must, when running at full speed, have too little compression; but by their aid M. Normand is able to give ample compression at full speed and yet run no risk at low speeds when working very expansively. The valves open at each stroke, permitting the surplus steam to escape into the chimney before the admission port opens. These valves have worked satisfactorily up to the present, with the exception that a guide was broken in one valve in torpedo boat 126. The guides in this case were secured to the valve by screws; since, they have been cast in one with the valve. The frames of the engine are of gun metal with diagonal steel ties. The slide bars are of bronze, grooved for oil, and with water circulation through them. The piston and connecting rods are of steel. The condenser tubes are fixed by rolling into the tube plates. They are bent slightly to permit contraction and expansion. No packing of any kind is used. This method is said to answer perfectly. The feed water is cleared of grease and dirt by being passed through a sponge filter. The sponge arrests the grease but lets the water pass freely. The feed is next passed through a heater, consisting of a sheaf of tubes rolled into plates at each end. The sheaf is placed in a copper vessel. The feed water

circulates round the tubes. A special valve worked by an eccentric on the after end of the crank shaft admits, during the period of expansion, steam from the large cylinder to the heater at each stroke. This steam moves through the tubes in a direction opposite to that in which the water moves. The water at slow speed is raised to a temperature of about 158 degrees Fahr.; at full speed it is heated to 212 degrees Fahr. The water resulting from the condensation of the steam passes by a steam trap to the condenser. A second and similar trap drains the jackets, and the hot water is passed through a copper coil in the hot well, so that it gives up its heat to the feed water before entering the condenser.

The accompanying table gives the results of the trials for economy:

TABLE OF RESULTS, SLOW SPEED.

	First day.	Second day.
Total number of revolutions	67,100	64,577
Speed in knots	10.819	10.412
Consumption of coal:		
Total during eight hours	926 lb.	881 lb.
Per hour	127 lb.	110 lb.
Per hour and square foot of grate	7.5 lb.	6.5 lb.
Per knot	11.75 lb.	10.75 lb.
Per knot at ten knots	10 lb.	10.2 lb.
Water per hour	1,988 lb.	1,988 lb.
Indicated horse-power	119.95 lb.	112.33 lb.
Coal per horse per hour	1.054 lb.	.979 lb.

The extreme economy obtained during these trials is attributable to two causes: in the first place, the boiler was very economical; in the second, the engines used the steam supplied to them to the best advantage. The report of the commission estimates the theoretical value of the fuel, which was special torpedo boat briquettes from Anzin, at 16 lb. of steam to the pound of fuel. The boiler actually made 12 lb. per pound of coal, so that the efficiency was 75 per cent., a very excellent result. During the trial the grate area was reduced by fire tiles to a little over 17 square feet; the fans were not worked, and the stokehold hatches were open all the time. The heating surface stood in the ratio

of 81.6 to 1 of the grate surface. M. Normand attaches much importance to the arrangement of the tubes in the tube plates, and he cites a very remarkable experiment made with a locomotive boiler. A cock was fitted on the shell of this boiler, and from the cock a small-bore tube was led down through the water to a point in close proximity to the tube plate of the fire box. When the boiler was worked at full power, with a sharp draft, no water could be got from the cock; nothing but steam. This is a highly suggestive experiment, and does much to explain why tubes become leaky when forced draft is used. M. Normand classifies the causes of the exceptional economy of his engines under four heads: first, the great economical efficiency of the boiler; second, the complete compression in the small cylinder, by which clearance was eliminated; thirdly, the heating of the feed water; fourthly, the superheating of the steam due to throttling.

In dealing with the first point M. Normand lays much stress on the necessity for diffusing the products of combustion equally through all the tubes, pointing out that when the draft is sharp and the tube area ample the gases may select certain tubes or rows of tubes, leaving the others inefficient.

Concerning compression, while M. Normand does not ignore the benefit derived from annihilating clearance, which amounted to 10.6 per cent. in the small and 6.4 per cent. in the large cylinder, he holds that much economy results from the fact that compression so heats up the metal that initial cylinder condensation is much reduced. This method of reheating M. Normand regards as much more efficient than a steam jacket, because it operates directly on the surface of the cylinder instead of being transmitted through the walls. That compression has not been fully utilized heretofore is, he maintains, because of the want of the relief valves, which he has provided.

As to the system of heating the feed which he adopts, M. Normand states that although the principle is that of McNab and Weir, his arrangement is much more practical; and although he gives the theory of the system, he attaches little

importance to that. The results in practice are eminently satisfactory, and with that he is content.

M. Normand points out that although superheating by throttling is by no means the best way theoretically, it is the best practically, because superheaters in the uptake are liable to be burned out, especially when combustion takes place, as is not uncommon, in the uptake. In water-tube boilers throttling is commonly adopted, notably in Belleville boilers, which constantly carry 10 pounds per inch more than the steam-pipe pressure; and he cites the experiments of M. Benazé with the S. S. *Champlain* as a proof of the economy to be obtained by wire-drawing. M. Normand doubts whether it will be advisable to carry higher boiler pressures than those now used, and suggests that it may be found advisable to augment the diameters of the cylinders a little in order to get the same power with a lower initial—throttled—pressure. Notwithstanding the admirable results he has obtained with compound engines, he is putting triple-expansion engines into twenty-three boats he is now building, principally because he obtains a more equable turning moment on the crank shaft.

It is not surprising that the statements contained in the report from which we have quoted evoked some criticism in the discussion which followed the reading of M. Normand's paper; but it is noteworthy that none of the speakers seemed to be able to detect the locality of the error, if there was one. As the boiler produced 12 pounds of steam for each pound of fuel burned, and the consumption was 1.25 pounds nearly per English horse-power per hour, we have $12 \times 1.25 = 15$ pounds as the weight of steam used per horse per hour. This is an extremely small consumption, but not impossible. It has been exceeded with some pumping engines, for example. But it appears yet smaller when we consider that the pressure during the trial did not exceed 60 pounds above the atmosphere. We see no reason to doubt the substantial accuracy of the report. The diagrams were taken every half hour; the briquettes put on board before the eight hours' run were weighed, those left unburned were weighed after the run, and the difference was the

consumption. The feed water was not measured, however, and the evaporation of 12 to 1 has been deduced from that of a Scotch boiler in the S. S. *Chasseur*, which was found by actual experiment to make 9.29 pounds of steam per pound of coal. We believe that the actual efficiency of the torpedo-boat boiler has been under-estimated.

RESULT OF OFFICIAL HIGH SPEED TRIALS.

	Speed in knots.	Revolutions per minute.	Pressures.		Consumption of fuel per hour.
			Boiler.	Receiver.	
No. 126, two hours...	21.087	308	135 lb.	33 lb.	1,892 lb.
No. 127, two hours.....	20.695	287.5	138 lb.	37 lb.	1,760 lb.
No. 128, two hours.....	20.975	308.5	138 lb.	32 lb.	2,068 lb.
Mean for the three boats.....	—	—	—	—	1,907.4 lb.
Average I.H.P., 1,000.....	—	—	—	—	—
Consumption per I.H.P. per hour.....	—	—	—	—	1.907 lb.

The heating surface for the power was enormous, the rate of combustion very slow, and the firing conducted with great care, the briquettes being broken into small pieces.

The feed water was raised to a high temperature. Under the circumstances, we think we may take the evaporation as more nearly 13 pounds than 12 pounds of water per pound of fuel, and the consumption then becomes $13 \times 1.25 = 16.25$ pounds, which is not exceptional, although very good. Nothing is known with certainty as to the consumption when the boat is running at full speed. It is of course considerably in excess of that reported for the low speed. The preceding table gives the particulars of the official trials.

The entire experiment is very instructive, and the results all go to teach the same truth, namely, that maximum economy can only be had by using dry steam and neutralizing the effect of clearance. The performance of the machinery as a whole reflects very great credit on M. Normand.—*London Engineer of January 30, 1891.*

Jauréguiberry.—The plans for this first-class armored ship have

been approved by the Minister of Marine. The following are some dimensions and data:

Length, 355.9 feet; beam, 72.65 feet; draught aft, 27.72 feet; displacement, 11,605 tons; I.H.P., 13,049; speed with natural draft, 17 knots. Armor: An armor belt of a thickness varying from 10.82 to 17.72 inches; an armored deck 2.76 inches thick, and a cofferdam backed by 3.94-inch plates. The armament consists of two 11.91 and two 10.63-inch guns in turrets, eight 5.51-inch guns, four 2.56-inch and twelve 1.85-inch rapid-fire guns, eight 1.46-inch revolving cannon and six torpedo tubes. The turrets for the heavy guns occupy the angles of a parallelogram, two being amidships and two at the sides. They carry 14.57 inches of armor. The 5.51-inch guns are mounted in pairs in small turrets of 3.94-inch plates. A peculiarity of the ship is the application of electric apparatus for turning the turrets and closing ports, and for driving auxiliary machinery in most of the compartments. There are twenty-four d'Allest boilers furnishing steam of 215 pounds pressure.

Wattignies.—Torpedo-cruiser, has been launched at Rochefort. This vessel is of the *Condor* type, somewhat enlarged to allow of heavier machinery. Length, 232.9 feet; beam, 29.2 feet; draught aft, 15.4 feet; draught forward, 12.4 feet; displacement, 1,286 tons; speed, 18 knots; I.H.P., 4,000. Steam is furnished by four 2-furnace tubulous boilers; coal supply, 116 tons, on which the vessel can steam 552 miles at full speed, and 1,800 miles at 12½ knots.

Breakdowns of machinery during the fleet manœuvres of 1890.—The number of casualties was comparatively great. They were, for the most part, restricted to one class of ships, however, the torpedo chasers. The armored ships and the cruisers, even those made ready for sea in a hurry for the occasion, did fairly well. The machinery, to be sure, was not at any time pushed. The light cruisers *Forbin*, *Vautour* and *Epervier* all suffered derangements, but only in the case of the last did these assume a serious character necessitating the ship's running into port.

The torpedo chasers, vessels of 395 tons displacement, 2,000 I.H.P., and 18 to 19 knots speed, were a constant source of

worry and delay. Their boilers were constantly leaking; they were forever running short of water, and had to be towed again and again; all this while steaming at a speed of 8 knots. It was demonstrated beyond all doubt that the machinery of these boats is too light, and that they must receive stronger and heavier engines and boilers, even at the expense of speed.

The locomotive boilers will probably be taken out, and those of another system substituted, perhaps d'Allest boilers, with which the *Lance* and *Sainte Barbe* are now being fitted. Light machinery was, however, not the only cause for the breakdowns. The lack of experience on the part of the firemen had much to do with them. As a result of these manœuvres one hundred torpedo-boat firemen have, in Brest, been detailed to the various ships to assist the regular stokers. The results have been so satisfactory that the Minister of Marine has issued a decree ordering that all men holding the certificate of fireman were to be in future trained as torpedo-boat stokers.

RUSSIA.

The torpedo cruiser *Kasarski* has made a trip from Pillau to Sebastopol, during which a number of useful observations were recorded. This boat (built by Schichau at the beginning of 1890, see p. 426 of Vol. II of the JOURNAL,) has a length of 190 feet, beam of 24 feet, and draught aft of 11 feet, forward of 7. One triple-expansion engine develops an I.H.P. of 3,300. The cruiser ran the distance of 4,500 miles in 343 hours, at a mean speed of 12.28 knots. This low speed was necessitated by the exceptionally heavy weather experienced. A speed of 15 to 16 knots can be maintained without any undue exertions on the part of the fire-room force. The forced-draft speed is 21 knots. The boat is able to steam at the very low speed of 3 knots. In the Black Sea a run of 58 miles was made in 2¾ hours, and the double distance might have been run at that rate had circumstances required it. At sea the cruiser behaves well with the sea on the quarter and abeam; against a heavy sea she buries her bow and ships much water, of which she can free herself but slowly, and the speed must be reduced. The coal capacity

is 90 tons, on which the cruiser can steam 4,000 miles at 8 to 10 knots; 1,500 miles at 15 to 16 knots; 800 miles at 18 to 19 knots, and 500 miles at maximum speed, 20 to 21 knots.

The cruiser carries a steam anchor engine and a steam steering gear, which constitute an extra load without being of any use. The former is not powerful enough to weigh the anchor if it holds well. The latter is superfluous, because the hand gear is all that is required even at extreme speeds. Besides, the steam steering gear takes up much room, introduces unnecessary complication, weighs considerable, is liable to get out of order, and adds to the cost of the vessel. Concerning the bow rudder it may be said, that if it is intended by its use to back the vessel without exposing the broadside to the enemy's fire, it fails of its purpose, because the cruiser obeys this rudder only while backing slowly in smooth water. For turning while going ahead the bow rudder renders good service, reducing the circle by nearly one-half. One disadvantage connected with the bow rudder is, that owing to the sharpness of the bow, the anchor is liable to catch on the keel near the rudder, so that the latter must be hoisted up out of the way.

The armament consists of two torpedo-discharge apparatus. The cruiser was to have received besides nine 47-mm. Hotchkiss guns. These she will not be able to carry, as each gun with mounting weighs 2,162 pounds. This weight, carried on the upper deck, would interfere seriously with seaworthiness and speed, qualities of supreme importance in a craft of this kind.

ITALY.

Experiments conducted on board the armored ships *Castelfiardo* and *Ancona* to test the suitability of petroleum fuel for use on shipboard, have resulted favorably. The apparatus used is an invention of Capt. Cuniberti. It is claimed that petroleum is cheaper than coal, and that a battle ship can keep the sea three times as long as it was possible with coal. As a result of these experiments a course of instruction to make known the best method of procedure in firing with liquid fuel is to be opened on the *Ancona*.

Aretusa.—A modified *Tripoli*, 846 tons displacement, 4,000 I.H.P., speed 18 knots, was launched recently.

SPAIN.

Pelayo.—The first-class cruiser *Pelayo*, which has recently been added to the Spanish fleet, was built by the French Compagnie des Forges et Chantiers, at La Seyne, near Toulon.

The following are the principal dimensions:

Extreme length,	346.46 feet.
Beam at water line,	66.25 feet.
Depth amidships,	24.10 feet.
Draught,	24.79 feet.
Displacement at this draught,	9,900 tons.

The I.H.P. required on the trial was, under natural draft, 6,800, and under these conditions a speed of 15 knots was expected.

The ship is constructed throughout of steel. From end to end of the hull, above the water line is a steel armor-belt of a single row of plates 6 feet 10 inches high, and tapering in thickness from 17.7 inches amidships, to 11.81 inches at the ends. This is supplemented by a steel protective deck placed on a level with the top of the armor plates. All openings in this deck are surrounded with casings 39 inches high and 11.8 inches thick. The armament comprises two Hontoria 12.6-inches guns mounted, one forward the other aft, in Canet barbette turrets; two Hontoria 11.02-inches guns on Canet mountings, almost amidships, one on each side; one Hontoria 6.29-inch bow chaser; twelve Hontoria 4.72-inch guns on Canet carriages in broadside; a large number of quick-firing guns and revolving cannon; seven torpedo-firing tubes on the lower deck, above the armored deck. The barbette turrets have armor 15.75 inches thick, and ammunition tubes 7.87 inches thick. The forward gun is 31 feet 2 inches above water, and has an angle of train of 250°; the after one has an angle of train of 220°. The broadside guns have an angle of train of 180°.

The bunker capacity is 800 tons, and the coal is so arranged as to afford protection to boilers and machinery.

The propelling machinery comprises the following: two in-

dependent sets of main engines, each driving a propeller, and each consisting of a pair of compound engines so coupled that they can be worked together or separately; two sets of auxiliary engines, which drive the circulating and air pumps; twelve return-flue boilers, designed for a working pressure of 82 pounds. These boilers are divided into groups of three, placed in separate compartments with a large fan in each. There are two masts with military tops. The spread of canvas is 6,000 square feet.

The official trials of the machinery were divided into three series, the first being a speed trial with natural draft, the second being a speed trial under a forced draft of not more than 1.18 inches of water, the third trial being for the determination of the fuel consumption.

The results of the several trials are briefly as follows: Under natural draft a speed of 16.2 knots was obtained, being 1.2 in excess of the contract stipulations. Inasmuch as the second trial referred to the performance of the machinery alone, without reference to speed, no data is given.

The coal consumption trial demonstrated that a speed of 12 knots an hour could be maintained for 24 consecutive hours on a consumption of 45 tons of coal, showing a marked improvement on the prescribed maximum of 70 tons a day.

The *Pelayo* has been under construction since 1884. She was launched in 1888.

TURKEY.

A sea-going torpedo boat, built for the Turkish Government by the Germania Co. recently arrived at Constantinople. The boat is 160.7 feet long, 18.37 feet beam; the draught aft is 7.22 feet, forward 4.26 feet. It is driven by twin screws, the engines being of 2,500 I.H.P.; compound engines of 60 I.H.P. drive the ventilating fan and the pumps, as the triple-expansion engines used for this purpose on the five other similar boats have not given satisfaction.

The maximum speed is 24 knots, the sustained speed is 21½ knots. With forced draft, steaming at the rate of 21½ knots, 48 tons of coal are used in 24 hours; with natural draft a speed of 14 knots is maintained at a coal expenditure in 24 hours of 8

tons. The bunkers hold 50 tons; 15 tons can be taken on board in addition. On this supply the boat can steam 8 days and make 2,400 miles. The space between the engines is taken up by fresh water tanks. There are two torpedo discharge tubes, the one in the bow arranged for compressed air, that at the stern for powder. The boat carries three torpedoes. It is armed besides with five 37-mm. Hotchkiss guns. The hull is divided into seven compartments. There are two rudders, steam-steering and anchor-hoisting gear, and three masts.

ARGENTINE REPUBLIC.

Espora and *Rosales.*—The Argentine Government has recently acquired from the works of Messrs. Laird Bros., at Birkenhead, two torpedo gunboats, bearing the names of *Espora* and *Rosales.*

Owing to the conditions of the service for which these craft were constructed, their draught was limited to a maximum of 8.5 feet. In actual practice, however, a draught of not greater than 8 feet was secured.

The principal dimensions of these vessels are as follows:

Length,	200	feet.
Beam,	25	feet.
Depth, moulded,	13.5	feet.
Mean draught,	8	feet.
Displacement at this draught,	520	tons.
Freeboard, amidships,	5	feet.

Steel is the material employed throughout in their construction, and the same metal is used for the stem, stern frame, rudder frame and propeller brackets.

The maximum coal capacity is 130 tons, the normal supply being 100 tons, and this is so distributed as to afford considerable protection to engines and boilers.

Steam is generated by four boilers of the locomotive type, built of steel, with steel fire-boxes.

The steam pressure for which these boilers are designed is 150 pounds. The total grate surface is 140 square feet, and the heating surface is 5,415 square feet. Ample provision is made for steaming under forced draft, but ordinarily natural

draft will be employed. With the normal coal supply of 100 tons, it is estimated that these vessels have a radius of action of 3,000 miles at a mean speed of 10 knots an hour.

The propelling machinery consists of two sets of triple-expansion inverted vertical engines having cylinders of 19 inches, 28.5 inches and 42 inches diameter, with a common stroke of 19.5 inches.

Piston valves are used for the H.P. cylinders, but the ordinary D-slide valves are used for the I.P. and L.P. cylinders. Joy's assistant cylinder is employed to relieve a portion of the strain on the L.P. valves.

The condensers are of copper, of circular section, the water being circulated by centrifugal pumps.

The propellers are of manganese bronze, three-bladed, 6.25 feet in diameter, 7.5 feet pitch in the *Rosales*, and of 6.375 feet diameter, 8.083 feet pitch in the *Espora*, the total blade area being 13.5 and 13.75 square feet respectively.

On the coal-consumption trials of these two vessels, it was demonstrated that at a speed of 10.80 knots per hour the consumption of fuel was 66 pounds per knot, equivalent to a steaming distance on 100 tons of coal of over 3,000 miles.

The following table gives in detail the data determined by the official trials of the *Espora* and *Rosales*:

	Espora.	*Rosales.*
Mean draft	7 feet 11¾ inches.	7 feet 11½ inches.
Displacement	517 tons.	515 tons.
I.M.S.	155.3 square feet.	157.7 square feet.
Boiler pressure	150 pounds.	145 pounds.
I.P. receiver	55 pounds.	52 pounds.
L.P. receiver	10.2 pounds.	7.5 pounds.
Air pressure in fire room	2.6 inches.	2.5 inches.
Vacuum in condenser	26.5 inches.	29 inches.
Revolutions of engines	312	334
Total I.H.P.	3,448	3,532
Mean speed	19.823 knots.	19.76 knots.
Diameter of screw	6 feet 4½ inches.	6 feet 3 inches.
Pitch of screw	8 feet 1 inch.	7 feet 6 inches.
Total blade area	13.75 square feet.	13.5 square feet.

CHILI.

Capitan Prat.—This is the name of an armored cruiser built for the Government of Chili by the Compagnie des Forges et Chantiers, at La Seyne, and which was launched a short time since. She is now being completed for service.

Length,	325 feet.
Extreme breadth,	60 feet.
Mean draught,	25 feet.
Displacement at this draught,	6,900 tons.

The engines are of the triple-expansion type, designed to develop 8,000 I.H.P., and giving a speed of 19 knots under forced draft.

MERCHANT STEAMERS.

The indicator cards of the S. S. *Majestic*, shown on the plate opposite, were obtained through the kindness of the Chief Engineer of the vessel, Mr. W. T. Sewell.

Norddeutcher Lloyd S. S. *Havel*.—This new steamer was built by the Vulcan Company, of Stettin, and has been placed by her owners on the line running between Bremen, Southampton and New York.

This vessel is of 9,000 tons register, and is of the following dimensions:

Length,	485 feet.
Beam,	52 feet.
Depth of hold, moulded,	38 feet.

She has accomodations for no less than 826 passengers of all classes.

Her complement of officers and crew numbers 240 men.

The main engine is a five-cylinder vertical triple-expansion engine. Cylinder diameters: H.P. (2) 38 in.; I.P. 75; L.P. (2) 100. The H.P. cylinders are placed on top of the L.P., the I.P. being in the middle.

The estimated I.H.P. is 14,000.

Steam is furnished by ten boilers, six of which are double-ended, the other four being single-ended. Each boiler is 15.5 feet in diameter, the length of the double-ended ones being 18.66 feet, while that of the single-ended boilers is 10.33 feet.

These boilers are constructed entirely of steel, and are designed for a working pressure of 160 pounds above the atmosphere.

Fürst Bismarck.—The latest addition to the fleet of the Hamburg-American Packet Co. is the twin-screw steel steamer built by the Vulcan Co., at Stettin, Germany, named the *Fürst Bis-*

X

Indicator Card

March

Starboard Engine.

Revolutions = 85
I.H.P. = 95316

Diam. of Cyls. 43", 68",
Steam 180 lbs. 1st Receiv
Vacuum 26 ins. — Head w
Throttle wide open. Speed of
Total I.H.P. =

r Cards of S.S. Majestic.
March 15th 1891.

Port Engine.

Pm = 85.5
I.H.P.=1599.2

Pm = 88.87
I.H.P.=1633

H. P. Cyl.
Scale ½
Cut off 41 ins.

Pm = 79.92
I.H.P.=1469

Pm = 29.25
I.H.P.=1368.2

Pm = 28.5
I.H.P.=1309.7

I. P. Cyl.
Scale ½
Cut off 40.

Pm = 26.32
I.H.P.=1209.6

Pm = 12.98
I.H.P.=1682.6

Pm = 13.5
I.H.P.=1623.2

L. P. Cyl.
Scale ½
Cut off 45.

Pm = 12.84
I.H.P.=1544

Revolutions = 83.5
I.H.P. = 8788.5

45", 68", 110" × 60" stroke.
1st Receiver 65 lbs. 2d Receiver 16 lbs.
– Head wind and sea, no sails.
Speed of screw 23.7; Speed of Ship 20.2
at I.H.P. – 18320.1

marck. The principal dimensions of this fine vessel are as follows:

Length,	520 feet.
Beam,	58 feet.
Depth,	40 feet.
Displacement,	12,000 tons.

The propelling machinery comprises two sets of inverted vertical triple-expansion engines, each set in a water-tight compartment.

The cylinders are 40 inches, 66 inches and 101 inches in diameter, having a common stroke of 66 inches, and are constructed to develop 16,000 I.H.P. Steam is supplied by nine double-ended steel boilers of 17.25 feet in length and 15.33 feet in diameter.

The total heating surface is calculated at 35,000 square feet, the grate surface being 1,220 square feet.

These boilers are designed for a working pressure of 150 pounds. The crank shafts are each 20.5 inches in diameter.

On a recent trial the *Fürst Bismarck* developed an I.H.P. of 16,400, and a speed of 20.55 knots for four consecutive hours.

The twin-screws are of manganese bronze, each having three blades of 18 feet diameter, and 32 feet pitch. The total blade area is 96 square feet and the total disc area equals 509 square feet.

Polynesien.—The French "Compagnie Des Messageries Maritimes" have recently made a notable addition to their already efficient fleet of steamers in the *Polynesien.* This vessel is the third of the class of which the *Australien* and *Tasmanien* are the other two.

The *Polynesien* was built at La Ciotat, near Marseilles, and will run between that port and Australia, Sydney being the principal objective port.

The principal dimensions of the ship are as follows:

Length,	502	feet.
Beam,	59.5	feet.
Depth,	44	feet.
Draught,	24	feet.
Displacement at that draught,	8,638	tons.

A single screw is actuated by triple-expansion engines having cylinders of the following diameters: H.P., 44 inches; I.P., 67 inches; L.P., 106 inches, with a common stroke of 54 inches.

The working pressure is 180 pounds per square inch.

The revolutions of engines are 82 per minute, and the I.H.P. equals 7,650. An average speed of 18 knots has been maintained.

The *Polynesien*, in common with the others mentioned, is fitted with the Belleville tubulous boiler, there being twenty in this vessel, in two groups of ten each, there being two smokepipes. The boilers here mentioned are designed for a working pressure of 200 pounds. The total grate surface of the twenty boilers is 633 square feet, the total heating surface being 23,000 square feet. The floor space occupied by the boilers and fire rooms is 84.75 feet fore-and-aft by 29.5 athwartship.

Dunottar Castle.—One of the most notable recent additions to the steam merchant marine of England, is the South African Mail Steamer *Dunottar Castle*, belonging to the "Castle Line" of Messrs. Donald, Currie & Co. This vessel is not only the largest of their fleet, but is distinctly the fastest.

The *Dunottar Castle* was built and engined by the Fairfield Ship-building and Engineering Company, and is of the following dimensions:

Length over all,	435 feet.
Breadth,	50 feet.
Depth,	36 feet.
Registered tonnage,	5,465 tons.

She is built of steel throughout, having a continuous cellular double bottom for water ballast. The pump for emptying these ballast tanks is arranged to pump water from the bilge as well. The ship is divided into nine water-tight compartments.

The motive power is furnished by the largest triple-expansion engines yet built for this company.

The dimensions of cylinders are:

High-pressure cylinder,	38 inches diameter.
Intermediate cylinder,	61.5 inches diameter.
Low-pressure cylinder,	100 inches diameter.
With a common stroke of	66 inches.

The high-pressure cylinder is fitted with a piston valve, and the other two cylinders each have a double-ported slide valve, all the valves being operated by double eccentrics and link motion.

The reversing engines are of the hydraulic type.

The bilge, feed and air pumps are driven from the cross-heads of the high-pressure and low-pressure engines.

The main crank shaft is in three built-up interchangeable pieces.

The crank, thrust, line and propeller sections of the main shaft are forged from Siemens-Martin mild steel, having been built by Messrs. Vickers, Sons & Co., of Sheffield.

The line shaft and propeller shaft is hollow, the diameter of the first named being 18.25 inches and of the latter 20.25 inches.

The thrust block is of the "horseshoe" type, the shoes being hollow and provided with water-circulating arrangements. The screw is of cast steel, having four blades secured to a cast-steel boss, the whole being supplied by Vickers, Sons & Co.

The circulating pumps of the main condensers are of the centrifugal type, each pump having a capacity of supplying water enough when the main engines are at full power.

A Weir's feed heater and two Weir's evaporators are in the engine room.

There is an auxiliary condenser with separate air and circulating pumps.

As this is the first installation of a double evaporator on the Weir system, a brief account of their operation may not be uninteresting to our readers.

Each evaporator is six feet in diameter and five feet long, being constructed of Siemens-Martin steel, and tested for a working pressure of 80 pounds per square inch. The daily capacity of these evaporators is given as 40 and 30 tons respectively of drinking water for ship's use. When the product is for this purpose the evaporators are worked on either the single or the double effect system, and when for boiler-feeding purposes the triple-effect system is employed.

The operation is as follows: Steam is admitted from the main

boilers through a special admission valve, this valve being fitted with a lock-up safety valve, the pressure being limited to one hundred and fifteen pounds. From this admission valve the steam is led into the high-pressure evaporator tubes; the condensed water goes to the hot well, and the evaporated steam to the heating tubes of the low-pressure evaporator. The condensed water of this evaporator is led to either of two fresh-water condensers, and the evaporated steam either to the fresh-water condensers or direct to the low-pressure receiver of the main engine.

The working pressure in the high-pressure evaporator is fifty pounds per square inch, and in the low-pressure fifteen pounds. The precaution for safety is important and worth noting. Both evaporators are made for eighty pounds working pressure, as before stated, but their safety valves are loaded for sixty pounds only.

This margin of safety is considered necessary by the inventors.

The evaporators are supplied with sea water by two auxiliary steam pumps of the same design as those fitted to all evaporators of this type in the Navy.

The boilers for supplying steam to the main engines are four in number, and are 15.25 feet in diameter and 18.66 feet long, double-ended, multitubular, and containing three Fox's corrugated furnaces at each end. These furnaces are 3.66 feet in diameter. The boilers are constructed entirely of steel, and are intended for a working pressure of 160 pounds. There are two smokepipes.

The speed trials of the *Dunottar Castle* recorded an average performance of seventeen knots an hour.

The first outward voyage from Dartmouth to Cape Town was made in sixteen days, eleven hours and fifty-four minutes, or nearly a day less than the same voyage has ever been previously made. The homeward voyage was made in sixteen days and six hours. This vessel is lighted throughout with electricity, the Siemens Brothers' system being employed.

In close proximity to the electric plant in the engine-room is a refrigerator of twenty thousand cubic feet, in connection with

which are three cold chambers. The air compressing engine is fitted in the passage between the engines and fire-rooms, having connections throughout the ship for ventilation.

For these engines, and for the various pumps, &c., in the ship, there is a separate single-ended boiler, with two furnaces; also an auxiliary surface condenser, fitted with separate air and circulating pumps, so that all auxiliary engines are entirely independent of the propelling machinery.

S. S. *Umbria*.—The care and exactness with which the leading English builders test their vessels on the trial trip is proverbial, and is almost as exact as that of a trial of a vessel of the Navy.

The notes of the trial of the S. S. *Umbria*, of the Cunard Line, on her trial trip for acceptance are very interesting, particularly in regard to the speed and horse-power required to drive the hull through the water.

The ship's dimensions are given in the table:

Moulded dimensions,	500 feet 2 inches by 57 feet.
Length on load water line,	500 feet.
Mean trial draught,	22.33 feet.
Depth of keel,	12 inches.
Moulded draught,	21.33 feet.
Displacement at above draught,	9,860 tons.
$\frac{\text{Displacement in tons} \times 35}{\text{Immersed midship section} \times \text{L.W.L.}}$ =	0.6902.
Area immersed midship section,	1,000 square feet.
Mean angle of entrance,	8 degrees 36 minutes.
Total wetted surface,	35,061 square feet.
Area of propeller disc, total,	471 square feet.
Area of propeller disc immersed,	435 square feet, the tips of blades being out of water.
$\frac{\text{Immersed area of propeller}}{\text{Wetted surface in 100 square feet}}$ =	1.25.
$\frac{D^2 \times S^3}{\text{I.H.P.}}$ =	263.80.

The speed of the ship was frequently taken, in fact, she was run at various known speeds, low to high, and the engines indi-

cated at the same time. From these known speeds a curve was constructed showing the ship's I.H.P. at any given speed, which is correct to all intents and purposes, the variation being very slight.

Speed in knots per hour.	Indicated horse-power.	Difference in horse-power per knot or half knot.	Speed in knots per hour.	Indicated horse-power.	Difference in horse-power per knot or half knot.
7	860		14	3,800	400
8	1,050	190	14.5	4,300	500
8.2	1,150	100	15	4,800	500
9	1,280	130	15.5	5,420	620
9.5	1,430	150	16	6,050	630
10	1,600	170	16.5	6,780	730
10.5	1,750	150	17	7,570	790
11	1,950	200	17.5	8,480	910
11.5	2,160	210	18	9,420	940
12	2,400	240	19	11,542	2,122
12.5	2,680	280	20	13,920	2,378
13	3,040	360	20.18	14,321	421
13.5	3,400	360			

Mooney, Thos.....Chief Draughtsman Morgan Iron Works, 9th street and E. R., New York.
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Moore, W. S., Passed Assistant Engineer, U. S. N.....U. S. S. *Vesuvius*.
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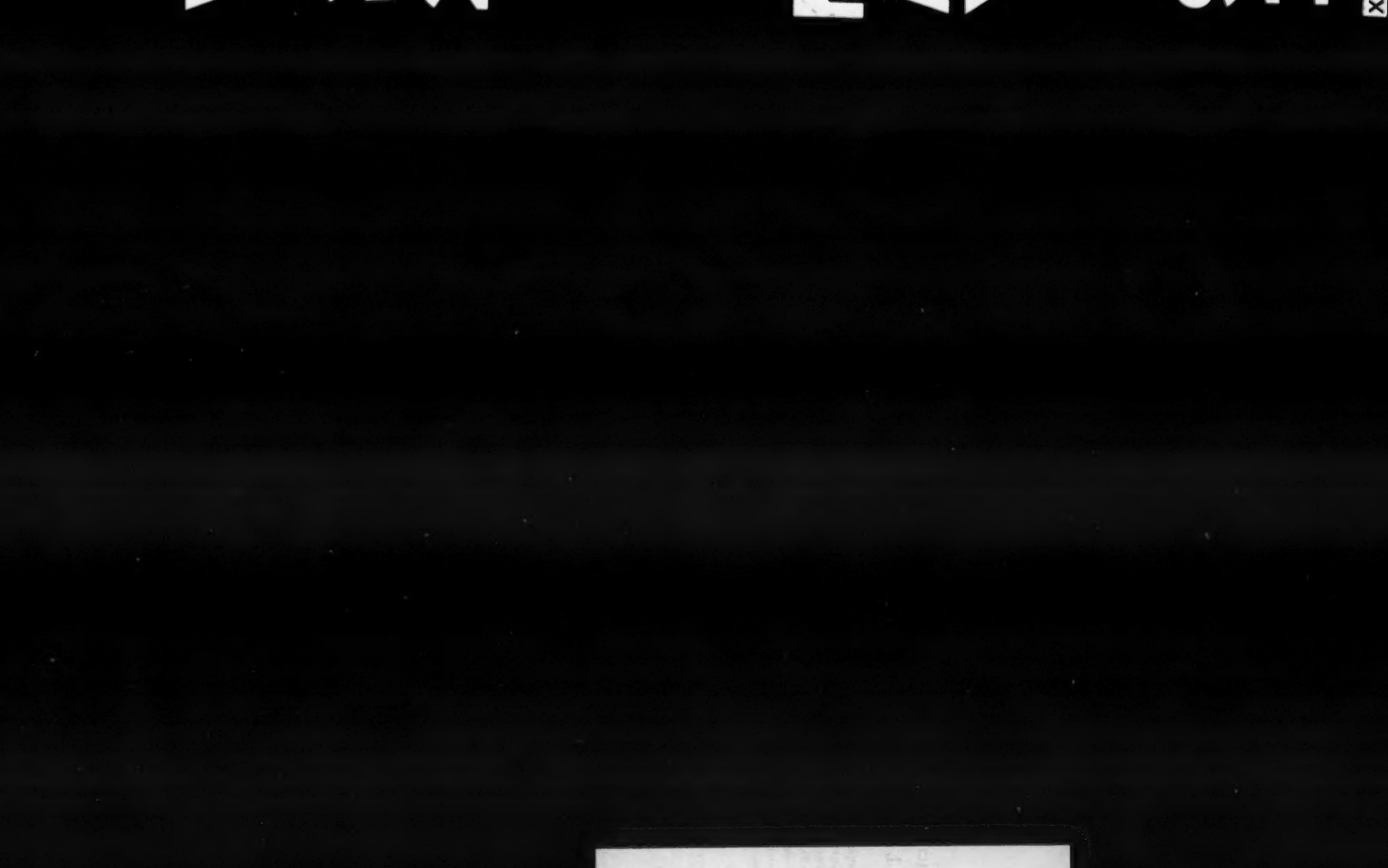
Morley, A. W., Chief Engineer, U. S. N .....Quintard Iron Works, 12th st. and Ave. D, New York.
Mosher, C. D., Designer and Builder of Yachts.....Amesbury, Mass.

The above names were inadvertently omitted from the list of members published in the last number of the JOURNAL.